Built Asset Sustainability, Rethinking Design, Construction and Operations
29 June - 01 July 2018 - Colombo

SYMPOSIUM PROCEEDINGS

29th June - 1st July 2018

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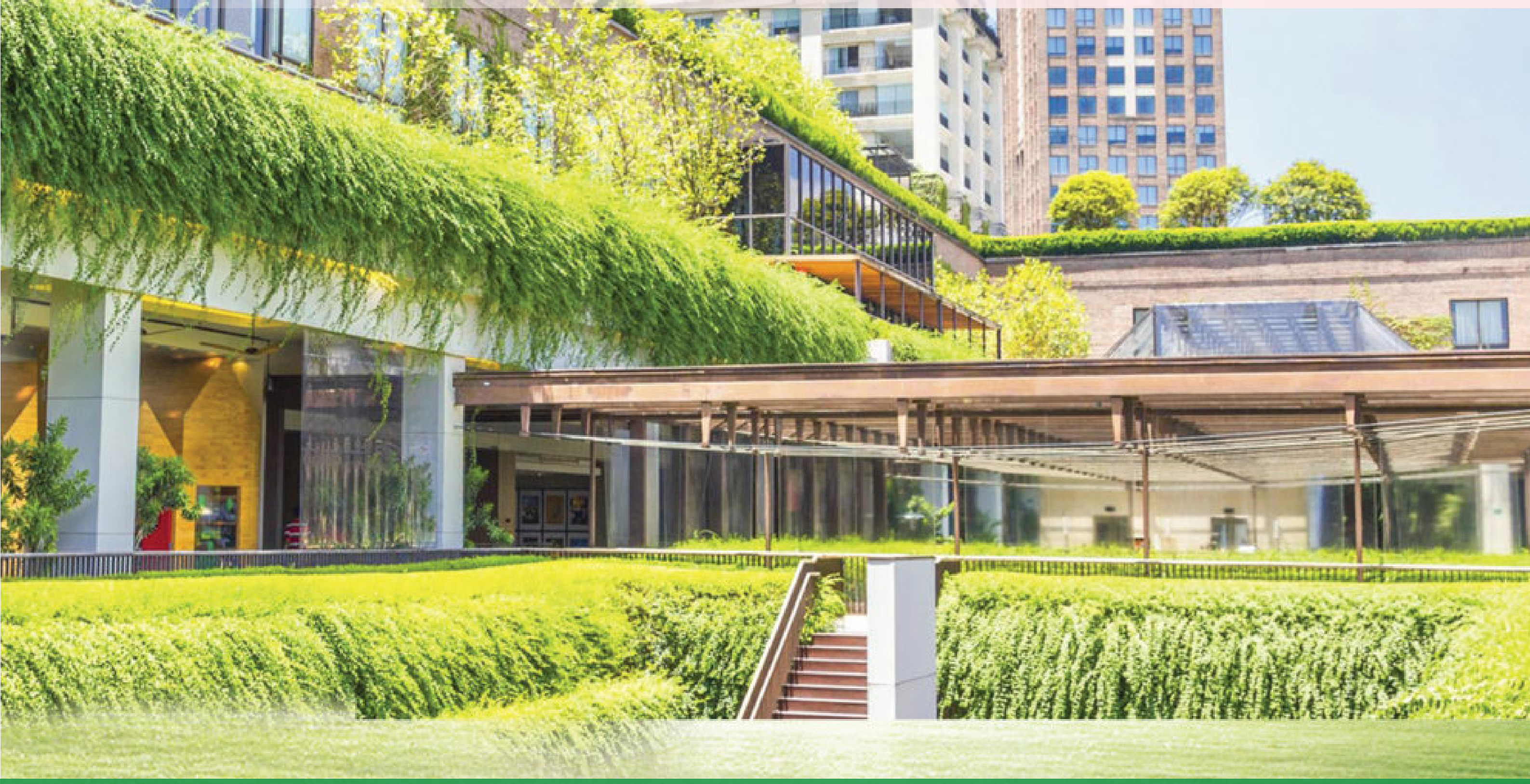

The 7th World Construction Symposium - 2018

Built Asset Sustainability: Rethinking Design, Construction and Operations

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PROCEEDINGS

THE 7TH WORLD CONSTRUCTION SYMPOSIUM 2018

THEME

BUILT ASSET SUSTAINABILITY: RETHINKING DESIGN, CONSTRUCTION AND OPERATIONS

EDITORS

Dr. Y.G. Sandanayake

Dr. S. Gunatilake

Dr. K.G.A.S. Waidyasekara

Building Economics and Management Research Unit (BEMRU)
Department of Building Economics
University of Moratuwa

Edited by Dr. Y. G. Sandanayake, Dr. S. Gunatilake and Dr. K.G.A.S. Waidyasekara

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We would like to express our sincere appreciation towards the Ceylon Institute of Builders (CIOB) for inviting Building Economics and Management Research Unit (BEMRU) of the Department of Building Economics, University of Moratuwa to jointly organise the 7th World Construction Symposium on the theme of “Built Asset Sustainability: Rethinking Design, Construction and Operations”. We also extend our sincere gratitude towards our associate partners: Liverpool John Moores University, United Kingdom; Centre for Innovation in Construction and Infrastructure Development (CICID), The University of Hong Kong, Hong Kong; Indian Institute of Technology Madras (IIT Madras), India; Western Sydney University, Australia; East Carolina University, USA; Colombo School of Construction Technology (CSCT), Sri Lanka; and CIB-W122: Public Private Partnership for their constant support. We are very thankful to the authors who have submitted papers for this symposium, as if not for them, we could not hold this event. Our special thanks also go to the eminent international and local scientific committee members for reviewing and offering constructive comments to make the papers more meaningful and contextual. We would like to extend our gratitude towards the chief guest, keynote speaker, session chairs, session coordinators, paper presenters and other invitees for their commitment and contribution to the symposium. Our special thanks go to Editor-in-Chief of BEPAM Journal, Emerald Group Publisher and their team for the contribution to the symposium. Further, we are thankful to the members and the facilitator of panel discussion on “Challenges for Creating Liveable Cities”. The Faculty of Graduate Studies, University of Moratuwa is also acknowledged with a great gratitude for sponsoring keynote speaker under the grant scheme on “Funding for International Conferences and Symposia 2018”. We are also thankful for the other organisations that have provided sponsorships.

Last but not least, a special thank you goes out to all our colleagues in the organising committee and symposium secretariat for devoting their time and effort to make ‘The 7th World Construction Symposium 2018’ a success.

Editors
The 7th World Construction Symposium 2018
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June 2018

PREFACE

The 7th World Construction Symposium jointly organised by the Ceylon Institute of Builders (CIOB) and Building Economics and Management Research Unit (BEMRU), Department of Building Economics, University of Moratuwa is held from 29 June - 1 July 2018 in Colombo with the partnerships of Liverpool John Moores University; Centre for Innovation in Construction and Infrastructure Development (CICID), The University of Hong Kong; Indian Institute of Technology Madras (IIT Madras); Western Sydney University; East Carolina University; Colombo School of Construction Technology (CSCT); CIB-W122: Public Private Partnership and Built Environment Project and Asset Management (BEPAM): Journal, published by Emerald Group Publishing. The symposium provides a special forum for academic researchers and industry practitioners to share their knowledge, experience and research findings on the main theme of "Built Asset Sustainability: Rethinking Design, Construction and Operations".

The sub themes of the symposium cover a wide spectrum of areas such as: Affordable Sustainability, Building Information Modelling and Information Management, Cost Management, Disaster Management, Education of Sustainable Construction, Energy Management, Entrepreneurship, Environmental Economics and Management, Green Buildings, Green Rating and Certification, Innovative Green Technologies, Legal Aspects Relating Sustainable Construction, Linking Design & Construction to Operation & Maintenance, Public Private Partnerships (PPPs) for a Sustainable Built Environment, Process Improvement, Procuring Sustainable Built Infrastructure, Resilience Buildings, Risk Management in Construction, Socio-Economic Sustainability, Sustainable Construction Practices, Sustainable Facilities, Sustainable Materials/Green Building Materials, Sustainable Procurement Strategies, Sustainable Urbanisation and Waste Management.

We received number of abstracts and full papers for the symposium and all papers went through a rigorous double-blind peer-review process by locally and internationally renowned reviewers with respect to the originality, significance, reliability, quality of presentation and relevance, prior to selection. After the rigorous double-blind review process, 63 papers were selected for publication. The authors of the selected papers are from a range of different countries including, Sri Lanka, India, United Kingdom, Australia, New Zealand, Singapore, China, Malaysia, Nigeria, UAE and Oman. Priority was given to the quality and standard of papers rather than the number of papers presented at the symposium. It is our firm belief that the publication that emerged from this symposium is the result of the tireless effort of all authors, reviewers, symposium organising committee members, associate partners, sponsors and that it would pave way for advancement of knowledge on built asset sustainability.

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KEYNOTE SPEAKER

Prof. Peter McDermott

Professor of Construction Management
School of the Built Environment
University of Salford
United Kingdom

Professor McDermott is a founder member and Joint Coordinator of the World CIB Working Commission (W92) into Construction Procurement. From this international perspective and from the academic base at Salford, Peter seeks to apply the results of research into the policy and practice nationally and regionally in the UK. Peter draws upon his own and others research work, demonstrating how effective procurement can be the lever for improved social and economic performance in the construction and infrastructure sectors. These ideas have been well rehearsed in the international literature, but are now playing out through public policy, with new developments around industrial strategy and an increasing emphasis on social value.

Peter will draw upon his experiences from having developed procurement and performance management systems with major regional and national public sector clients, and working national and regional infrastructure strategies. He will especially draw upon his experience as a developer of and independent member of the Board for the North West Construction Hub (NWCH) strategic framework and from chairing the change agency that is Constructing Excellence in the North-West of England.

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PAPERS

A SWOT ANALYSIS FOR SRI LANKAN CONSTRUCTION SMES

K.A.T.O. Ranadewa[1*], Y.G. Sandanayake[1] and Mohan Siriwardena[2]

[1]Department of Building Economics, University of Moratuwa, Sri Lanka

[2]Department of Built Environment, Liverpool John Moores University, United Kingdom

ABSTRACT

The significant benefits that Small & Medium Enterprise (SME)s provide to the national economy, including their contributions to the economic development, industrial output, employment creation, and tax revenue marked as the reasons for examining the various aspects of SMEs around the world. The construction industry is usually described as being one of the riskiest business arenas and hence, SMEs needs to improve their capacities by analysing the possible opportunities as well as the threats in the market to sustain in the construction industry. Hence, this paper explored the SWOT analysis for SME contractors in Sri Lanka. A literature review followed by five case studies were carried out to collect data. The collected data were analysed and presented in a SWOT matrix to identify the advantage of positive facts over negative facts for construction SMEs. As per the research findings, the explored external and internal factors can be categorised under five main themes as financial, technical, managerial, legal and political and other. Findings of the case studies identified 21 internal factors as the strengths of construction SMEs and 48 internal factors as weaknesses of construction SMEs. Yet, the study further revealed 22 factors under opportunities for construction SMEs and identified 46 external factors as threats to their organisation. This study further proves that a detailed understanding of the processes and extensive explorations of all possible causes, reasons using the SWOT analysis will help overcoming the number of challenges faced by construction SMEs. In addition, it was evident that inexpensive or zero cost solutions could be implemented by identifying the strengths and opportunities of their organisations. This will mark for further researches to study the possible strategies for construction SMEs using SWOT analysis matrix.

Keywords:*Construction SMEs; Sri Lanka; SWOT Analysis.*

1. INTRODUCTION

Construction SMEs are seen as playing a crucial role in the economy in terms of creating jobs contributing to economic growth and stability, still, keep one step below the large construction companies. Thus, there is a need to analyse the situation of construction SMEs with respect to possible threats as well as the opportunities to improve their strengths and overcome the weaknesses. To succeed in the construction industry, weaknesses must be overcome through strength and threats must be transferred into opportunities to build up the capacities of the organisations. Though studies that focus on some aspects of SWOT are available, there is a dearth of research that undertakes a comprehensive assessment of SWOT analysis in small-scale construction in Sri Lanka. Hence, this paper focuses on identification of strengths, weaknesses, opportunities, and threats of Sri Lankan SME contractors.

Even though construction SMEs largely contributing to country's economy, there is a lack of proper definition for them in the Sri Lankan context. Hence, this paper commences by defining SMEs and precisely defining construction SMEs in Sri Lankan context. Then a literature review carried out to analyse the characteristics of SMEs. Thereafter, presents the analysis of empirical data used to identify the SWOT for SME contractors in Sri Lanka. A detailed description of strengths, weaknesses, opportunities, and threats has been explored. It further discusses, the explored external and internal factors under five categorise as financial, technical,

[*]Corresponding Author: E-mail – tharushar@uom.lk

managerial, legal and political and other. The paper contributes to the body of construction SMEs, in particular towards the identification of SWOT in Sri Lankan SME contractors.

2. SMALL AND MEDIUM ENTERPRISES (SMEs)

There is no universally accepted definition for SME, as it seems to vary from country to country and also from industry to industry. Most of the available SME definitions are quantitative whereas only a few defined qualitatively. Ayanda and Laraba (2011) identified three (03) parameters generally applied by most countries to quantitatively define SMEs as capital investment in plant and machinery; number of workers employed and volume of production or turnover of the business. However, among many studies intended at arriving at a proper definition, Bolton (1971) claimed that a small firm could not be adequately defined in terms of employment or assets, turnover, output or any other arbitrary single quantity, nor would the same definition be appropriate throughout the economy. Accordingly, Bolton (1971) used following parameters to qualitatively/ economically define SMEs;

- Has a relatively small share of its market.
- Managed by its owners or part-owners in a personalized way.
- Does not form part of a larger enterprise and the owner-managers are free from outside control in taking their principal decisions.

Nevertheless, the economic definition is of no use for statistical purposes, since business statistics are not classified in terms of qualitative measures like market share, owner-managers, and independence (Bannock, 2005). Therefore, most of the countries/ industries do not use the above parameters and thus used quantitative parameters individually or in combination to define SME. However, Table 1 shows a summary of main definitions of SMEs related to some selected countries.

Table 1: Summary of Definitions of SMEs

Country	Sector		*Definition of SME*				Reference
			SMALL		MEDIUM		
	Manufacturing Sector	Service Sector	Annual Turnover (Mn)	No of Employees	Annual Turnover (Mn)	No of Employees	
Sri Lanka	x		SLRs. 16-250	11 < 50	SLRs.251-750	51-300	2
		x	SLRs. 16-250	11 < 50	SLRs.251-750	51-200	2
Canada	x		< CDN$ 5	< 100	CDN$ 5-20	100-500	1
		x	< CDN$ 5	< 50	CDN$ 5-20	50-100	1
China	x			50 - 100		101 -500	1
Indonesia	x					< 100	1
Korea	x					< 300	1
Malaysia	x				< RM 25	< 150	1
Philippines	x			10 < 100		100-199	1
Singapore		x				< 200	1
Taiwan		x				< 200	1
Thailand	x			< 50		50-200	1
Vietnam	x			< 30		30-200	1
EU Commission			< € 10	< 50	< € 50	< 250	3
USA						< 500	4

1 – Harvie (2004); 2 - Ministry of Industry and commerce (2015); 3 - EU Commission (2014); 4 – OECD (2005)

According to Table 1, there is no such dissimilarity between the SME definitions in the manufacturing sector and service sector. However, Harvie (2004) stated that the majority of SMEs are relatively small and over 95 percent of SMEs in the East-Asian region employ less than 100 people. SMEs are non-subsidiary, independent firms which employ less than a given number of employees. The most frequent upper limit designating an SME is 250 employees, as in the European Union. Yet, some countries set the limit at 50 employees, while the United States considers SMEs to include firms with fewer than 500 employees (OECD, 2005). Nevertheless, the upper limit of a number of people employed is not a must to be satisfied. Therefore, an organization which satisfies the turnover and balance sheet total requirements can still qualify as a SME even if it does not satisfy the employment requirement. This categorization has been derived mainly for accounting and reporting purposes. Thus, it is difficult to come up with a universal definition for SMEs due to the significant differences that exist within the SME sector, different industry sectors, countries, and economies etc. This has created numerous difficulties for researchers studying SMEs (Curran & Blackburn, 2001). According to Storey (1994), researchers have attempted to resolve these difficulties by tailoring definitions. However, practically difficult to use the entire criterion to define SME due to the sensitivity of data such as turnover, balance sheet totals.

2.1. CONSTRUCTION SMES IN SRI LANKA

The literature revealed that there is no published definition to the construction SMEs in Sri Lanka. Moreover, there is lack of published evidence to get the number of employees to define the SME category. Hence, the researcher developed the definition based on the SME definition in terms of annual turnover in Sri Lankan context (refer Table 1) and Construction Industry Development Authority (CIDA) registration for construction contractors in Sri Lanka (refer Table 2). CIDA is set up by the Government of Sri Lanka to develop and promote the domestic construction industry and hence, each and every organisation needs to get registered to be practice in Sri Lanka. Table 2 shows the financial limits for the grading of contractors as per CIDA registration.

Table 2: Contractor Grading According to CIDA Registration

Specialty	Grade	Financial Limit (Rs. Mn)
Building Construction	CS2	X > 3000
Highway Construction	CS1	3000 ≥ X > 1500
Bridge Construction	C1	1500 ≥ X > 600
Water Supply and Sewerage	C2	600 ≥ X > 300
Irrigation and Drainage Canals	C3	300 ≥ X > 150
Dredging and Reclamation	C4	150 ≥ X > 50
Storm Water disposal and Land Drainage	C5	50 ≥ X > 25
Maritime Construction	C6	25 ≥ X > 10
Heavy Construction (Areas to be Specified)	C7	10 ≥ X > 05
	C8	05 ≥ X > 02
	C9	02 ≥ X

Source: CIDA, 2015

As per Table 2 and the SME definition, medium-sized contractors for Sri Lanka can be categorized under whose annual turnover between Rs. 250 - 750Mn (Grade C3 – C2) and small-sized contractors having an annual turnover of 16 – 250 Mn (Grade C6 – C4). Hence, the category of construction SMEs for Sri Lanka is made up of contracting organisations which have a grade between C2 – C6 as per the CIDA (2015) registration. In most of the cases, micro enterprises are also read with SMEs for any policy related measure. However, there is lack of details regarding the micro level contractors and hence, ignored for this study.

2.2. CHARACTERISTICS OF CONSTRUCTION SMES

In the developed and newly developing countries, SMEs generally employ a large percentage of the workforce and are responsible for income generation opportunities. These enterprises can also be described as one of the main drivers for poverty alleviation (Agwu & Emeti, 2014). The construction industry is usually described as being one of the riskiest business arenas. SMEs face particularly harsh business environments. Ofori and Toor (2012) contended the risks faced by construction SMEs in developing countries as lack of job continuity, competition from the larger number of enterprises in the industry offering the same services, expectations of the business partners, greater stress on professionalism and transparency. Construction researchers such as Rymaszewska (2014) and Agwu and Emeti (2014) added low level of technology, lack of skilled workers, lack of access to international markets, as their constant issues.

One of the qualitative definition given by Scott and Bruce (1987) highlighted few major characteristics of small firms. Scott and Bruce (1987) have adopted the definition put forward by the American Committee for Economic Development which says a firm is small if; 'Management is independent. Usually, the managers are also owners, Capital is supplied and ownership is held by an individual or small group and area of operation is mainly local, Workers and owners are in one home community, but markets need not be local. Hence, the definition clearly stated the nature of the management of SMEs, the area of operations and market of SMEs. Yet, there is an uncertainty of SMEs to retain in local market even. One of the main characteristics of SMEs is high risk. Realizing the high-risk nature of SMEs, many governments have tried to improve SME capability (Wonglimpiyarat, 2015). Nevertheless, SMEs generally face difficulties in getting access to finance since investors do not prefer making investments in SMEs due to their risky nature of the business operation. However, access to finance has become an impediment to the success stories of SMEs.

There are significant differences between large companies and SMEs in their ability to absorb new knowledge because of their unique characteristics (Kamal & Flanagan, 2012). Numerous studies have attempted to explain the differences between these two enterprise clusters (Woschke et al., 2016), however very few have achieved their targets. Though governments and large corporations play a dominant role in the formal economy, SMEs drive the informal sector; hence, many developed and emerging nations aggressively pursue public policies designed to encourage SMEs (Awa et al., 2015). In the knowledge economy, the strength of SMEs is essentially determined by their ability to wisely take advantage of human intellectual capital and technology even more than traditional resources (Awa et al., 2015). Curran and Blackburn (2001) conferred three key characteristics of SMEs as uncertainty, innovation, and evolution. Moreover, Scott and Bruce (1987) have identified five stages of growth in a small business as; inception, survival, growth, expansion, and maturity. They further declare that the management and the structure of the organization fluctuate significantly through these stages. A significant majority of SMEs are local in their operations and rooted in local communities (Bannock, 2005).

SMEs often have more flexibility in their operations (European Communities, 2002). They can often be more flexible and responsive to customer needs than large integrated firms (OECD, 2004), as large firms, unlike SMEs, are constrained by large investments, formal structures, and procedures, etc. This distinct characteristic has allowed them to quickly adapt to changes happening in the business surroundings and gain a competitive advantage if they are willing to change. In addition to the characteristics mentioned above, Holmes and Gibson (2001) have identified a list of characteristics including; management and ownership is rarely separate, control over business operations and decisions resides with very few persons, the equity in the business is not publicly traded, the personal security of the owners is required to secure business debt; limited liability is rarely present, the level and the number of formal contractual relations are kept to a minimum level and personal objectives of owners will guide and directly influence business decisions. Hence, these distinctive characteristics of SMEs decide the evolution of SMEs.

2.3. SWOT FOR SMES

The continuous changes that affect the business environment, due to the globalisation process and the technology innovations, force SMEs to persistently look for new direction for the preserve and advance their market position (Aremu, 2004) while increasing their capacities. To be competitive in a global context and to meet unprecedented market changes, organisations must not only design and offer better products and services; but need to improve their operations and processes (Rahman et al., 2013). Therefore, a proper analysis of the SME organisation is paramount. Porters five force theory (Porter, 1979), SWOT analysis, PESTEL model and the Strategic group analysis (Dess et al., 2006) or similar theory can be used to analyse the prevailing condition of construction SMEs. However, it should be a powerful tool to analyse and understand the existing business environment and its attractiveness. Choice and use of strategic planning tools and techniques in SMEs by Kalkan & Bozkurt (2013) praised about the simplicity and practicality of SWOT analysis when comparing to other strategic planning tools. They further added that SWOT as a valuable management tool which may be easily absorbed with good effect into the realities and practicalities of an organization's existing planning and strategy formulation processes.

Given the pervasiveness of the use of the SWOT methodology by practitioners and academicians alike, it was not surprising a number of research studies focused on SWOT as a tool for strategic analysis. SWOT analysis could be used to analyse strengths, weaknesses, opportunities, and threats of any given matter (Kaplan Financial Limited, 2010). Though studies that focus on some aspects of SWOT are available, there is a dearth of research that undertakes a comprehensive assessment of SWOT analysis in SMEs. However, it is noteworthy that SMEs are higher in number than large-scale contractors in developing countries such as Sri Lanka which make it difficult to discount their contribution to economic growth and makes it imperative (Kamalanathan et al., 2014). Though Wasi and Skitmore, (2013) and Thwala and Mvubu (2008) have studied the challenges and problems facing small-scale construction in other countries, the findings do not quite suit the Sri Lankan construction industry due to the distinctive characteristics of the construction industry in Sri Lanka. However, their findings will guide the present research to study SWOT analysis for Sri Lankan construction SMEs.

3. RESEARCH METHODOLOGY

This research aimed to analyse the construction SMEs in Sri Lanka in terms of their strengths, weaknesses, opportunities, and threats. A literature review was carried out to explore the theoretical identification and correspondingly, multiple case studies were conducted. The profile of the case study organisations are summarised in Table 3.

Table 3: Profile of the Case Study Organisations Used for the Research

	Case A	Case B	Case C	Case D	Case E
Grade	C2	C2	C4	C4	C6
Size	Medium	Medium	Small	Small	Small
Nr of Employees	50	60	45	20	20
Nr of Projects in hand	11	05	04	03	03
Experience (years)	34	15	22	10	06
Field of activity	Building	Building	Building	Building	Building
Respondents	▪ Chairman ▪ Project Manager ▪ Site Engineer	▪ Managing Director ▪ Project Manager ▪ Site Engineer	▪ Managing Director ▪ Technical Officer ▪ Technical Officer	▪ Chairman ▪ Project manager ▪ Technical Officer	▪ Managing Director ▪ Technical Officer ▪ Technical Officer

The empirical data collection methods adopted within the case studies were semi-structured interviews with project participants, non-participant observations of progress meetings, and study of substantial of the project (Tender documents, meeting minutes, etc.). Employing semi-structured interview method is preferred in qualitative approach (Edwards & Holland, 2013) since the respondents have a structured flow to ask questions from interviewees. Three respondents from each case were interviewed. Moreover, observations and reviewing documents were undertaken to capture data. All five SME contractors represented different approaches and strategies with regard to SWOT in their projects. Hence, SWOT analysis used to investigate the construction SMEs in this research study. The explored external and internal factors were further categorised into financial, technical, managerial, legal and political and other factors. This categorisation assists in proper identification of SWOT by SMEs and to take necessary actions explicitly for each category.

4. SWOT ANALYSIS FOR SRI LANKAN CONSTRUCTION SMES

Findings of the case studies identified 21 internal factors as the strength of construction SMEs and 48 internal factors as weaknesses of construction SMEs. Yet, the study further revealed 22 factors under opportunities for construction SMEs and further identified 46 external factors as threats to their organisation. Moreover, they were categorized under five main themes as discuss in the next sections.

4.1. STRENGTHS OF CONSTRUCTION SMES

Table 4 discusses the strengths of construction SMEs with respect to the research findings. The identified strengths were further categorised to precisely identify financial strengths (FS), technical strengths (TS), managerial strengths (MS), legal and political strengths (LS) and other strengths (OS).

Table 4: Strengths of Construction SMEs

Strengths				
Financial	Technical	Legal & Political	Managerial	Other
FS1-Less capital required FS2-Flexible cash flows FS3-Less energy required	TS1-Small number of workers TS2-Few number of equipment TS3-Easy to train people TS4-Better control of the resources TS5-Action learning TS6-Low-tech work environment TS7-Quick reactions to problems TS8-Does not require high skills TS9-Use of traditional technologies	LS1-Favorable trade agreements LS2-Broad range of well-funded support institutions LS3-Widely shared visions and goals between public and private sector	MS1-Entrepreneurial Culture MS2-Independent workforce MS3-High flexibility and resilience to the dynamic changes MS4-Independent business firm MS5-Easy handling of workers	OS1-Competitive advantage over large companies

According to Table 4, construction SMEs has a competitive advantage over large construction companies due to the size of the organisation. As they are working on projects that are small in size, capital, and energy requirement is less which is a financial strength of the organisation. Use of traditional technologies in the low-tech work environment is an added advantage for construction SMEs and hence, they require a minimum number of workers, equipment and do not require high skills. Yet, they can quickly react to the problems within the site. The respondents further emphasized that there is a good control of the resources and hence, timely training of workers is another technical strength. Favourable trade agreement, a broad range of well-funded support institutions and widely shared visions/goals between public and private sector strengthened construction SMEs legally and politically. Entrepreneurial culture, independent workforce, high flexibility and resilience to the dynamic changes, independent business firm and easy handling of workers identified as the managerial strength of construction SMEs. Nevertheless, weaknesses of construction SMEs diluted the above-discussed strengths.

4.2. WEAKNESSES OF CONSTRUCTION SMES

Table 5 present the weaknesses of case study organisations as per the above categorisation.

Table 5: Weaknesses of Construction SMEs

Weaknesses				
Financial	Technical	Legal & Political	Managerial	Other
FW1-Lack of Capital FW2-Budget overrun FW3-Lack of cost controlling techniques FW4-Delaying payment FW5-High cost of construction	TW1-Lack of value addition TW2-Unable to meet the market demand TW3-Inadequate knowledge/techniques on process improvement TW4-Decreasing productivity TW5-Estimation errors TW6-High rate of collisions and accidents TW7-Design failure/ changes	LW1-Approach to economic development is not sufficiently holistic LW2-Internal Policies and Strategies of the parent organisation LW3-Less capital support from the government LW4-Difficulties in meeting regulations and policies of professional bodies	MW1-Lack of qualified professionals MW2-Not enough laborers MW3-Missing "Out of the box" strategies MW4-Insufficient research and development MW5-Lack of experience in conducting formal market research MW6-Lack of innovative solutions for products and services MW7-Lack of strategic leadership	OW1-Limited resources OW2-Limited networking OW3-Access to markets is limited OW4-Not enough facilities OW5-Lack of job continuity OW6-Difficulties in finding clients OW7-Continuous change of client's requirements

Weaknesses				
Financial	Technical	Legal & Political	Managerial	Other
	TW8-Increase of waste in projects TW9-Quality deficiencies in the output TW10-Workmanship issues TW11-Difficulties in technology transfer TW12-No innovation TW13-Limited use of information technologies TW14-Time overrun & missed deadlines		MW8-Poor Management Control MW9-Ineffective monitoring MW10-Lack of motivation in the workforce MW11-Shortage of effective marketing strategies and other support facilities MW12-Lack of formal procedures MW13-Not enough time to learn and reflect upon on lessons learned MW14-Lack of knowledge transfer MW15-Difficulties in technology transfer	OW8-Instability of the construction processes OW9-Lack of H & S awareness OW10-Poor H & S measures

Lack of capital, budget overrun, delaying payment and the high cost of construction were the financial weaknesses of construction SMEs. Yet, lack of cost controlling techniques will worsen the situation. Technical weaknesses include decreasing productivity, estimation errors, high rate of collisions and accidents, design failure/ changes, an increase of waste in projects, quality deficiencies in the output, workmanship issues, Time overrun and missed deadlines, limited use of information technologies and inability to meet the market demand. Hence, value addition in the organisation is low. Inadequate knowledge/techniques on process improvement and difficulties in technology transfer marked as the reasons for not implementing new construction tools and technologies within the construction process.

Most of the projects, construction SMEs work as a sub-contractor to a large construction company. Hence, internal policies and strategies of the parent organisation is another barrier to the independent development of the SME organisation. Similarly, there are difficulties in meeting regulations and policies of professional bodies. Even though the government provides special loan schemes for construction SMEs, less capital support from the government can be identified. Proper management of human resources marked as another success factor for any organisation. Yet, construction SMEs has a massive number of managerial weaknesses due to improper management of human resources. However, due to lack of qualified professionals and not enough labourers in the field, construction SMEs unable to get even the necessary amount of workers. Due to the monopoly created by large construction companies, SMEs has limited access to markets. Hence, difficult to find clients and hence, lead to limited networking within the construction industry. Continuous change of client's requirements is another weakness of construction SMEs and hence, they have no capacity to face the changing requirements. Moreover, they have limited resources, facilities and hence, construction processes are unstable all the times. Furthermore, lack of H & S awareness and poor H & S measures identified as the reasons for the increase of H & S issues. Yet, plenty of opportunities are available in the industry to overcome the weaknesses.

4.3. OPPORTUNITIES FOR CONSTRUCTION SMES

Table 6 shows the opportunities of construction SMEs as found from the research study.

Table 6: Opportunities for Construction SMEs

Opportunities				
Financial	Technical	Legal & Political	Managerial	Other
FO1-Special loan schemes form government and private bank FO2-Low interest rates for projects FO3-Tax reductions FO4-Availability of funds for research and innovations	TO1-Adding value to products (knowledge, services) TO2-Available of training programs for SMEs TO3-Availability of human resources TO4-Emergence of new technologies TO5-Availability of new process improvement methodologies	LO1-Unexploited linkages between different economic sectors LO2-Special incentives from the government LO3-Supportive legislations LO4-Significant long-term government support for the SME sector LO5-Professional bodies accreditations	MO1-Unexploited training programs for management Structure of the industry MO2-Transparency of the processes MO3-Adoptive for future needs MO4-Standardized processes for SMEs MO5-Continuous monitoring and evaluation from the government MO6-Availability of trainers/ expertise	OO1-Increasing public awareness about SMEs OO2-Target markets

Construction SMEs has largely contributed to the employ generation of an economy. Hence, special loan schemes form government and private banks provide at low-interest rates for projects. Further, SMEs getting tax reductions for some of the projects. Availability of funds for research and innovations is another financial opportunity that SMEs can get to overcome the financing problems. The research will not only provide money for the organisations but also lead to new process improvement methodologies. Moreover, the emergence of new technologies will change the traditional way of doing the businesses and hence, value addition to the product is enormous. Though some of the respondents doubt about the availability of human resources, the majority of respondents agreed that available human resources as a technical opportunity for construction SMEs. Moreover, nowadays a large number of training programs can be found for construction SME management as well as the shop floor workers.

Most of the respondents appreciated the seminars and workshops conducted by CIDA Sri Lanka for the benefit of construction SMEs. The government provides special incentives, supportive legislation, and significant long-term government support for the SME sector due to the unexploited linkages between different economic sectors. Furthermore, accreditations from professional bodies reinforced the quality of the projects carried out by them. Hence, some respondents highlighted the importance of getting accreditations from recognised institutions. The increase of public awareness about SMEs in the industry is another opportunity for construction SMEs. The case study further identified that even though trainers/ expertise are available in the field, the cost of hiring them is excessively high for the construction SMEs.

4.4. THREATS OF CONSTRUCTION SMES

The last phase of SWOT analysis is to identify the possible threat to the organisation. Hence, Table 7 summarised the threats identified during the research study for construction SMEs.

Table 7: Threats of Construction SMEs

Threats				
Financial	**Technical**	**Legal & Political**	**Managerial**	**Other**
FT1-Difficulties in access to finance FT2-Global financial crisis FT3-Capital supply	TT1-Equipment availability TT2-Material availability TT3-New construction technology	LT1-The demand of bribe by politician LT2-Change of government policy LT3-Continuous change in regulations	MT1-Shortage of labour MT2-Little flexibility in view of employment structure	OT1-Deficiencies in the construction industry OT2-Monopoly created by large construction companies OT3-Increasing competition within construction SMEs

Threats				
Financial	**Technical**	**Legal & Political**	**Managerial**	**Other**
FT4-Significant increase of energy cost FT5-High costs of construction FT6-High cost of labour FT7-High cost of material FT8-High cost of equipment FT9-High interest rates FT10-Availability of funds FT11-Hidden cost (back up, problem solving and solutions)	TT4-Lack of skilled workers TT5-Migration of Sri Lankan construction workers to neighbouring countries TT6-Poor Quality of material TT7-Poor Quality equipment	LT4-Occupational health/ safety related laws LT5-Difficulties in meeting regulations and policies of professional bodies LT6-Lack of specific standard regulations LT7-Instability of the political environment LT8-Increase of labor demands wage LT9-Taxations LT10Professional bodies accreditations	MT3-Trade Liberalization MT4-Lack of transparency MT5-Lack of professionalism MT6-Unfavorable procurement methods	OT4-Difficulties in finding clients OT5-Lack of access to international markets OT6-Unfavourable weather conditions OT7-Changing environment influences OT8-Nature/ inherent features of the construction industry OT9-Negative attitudes towards SMEs stability OT10-Lack of access to international markets OT11-Lack of professionalism among professionals OT12-Collisions and accidents

Difficulties in access to finance, high-interest rates, global financial crisis, capital supply and significant increase of energy cost are some of the constant threats in the industry for both construction SMEs as well as large construction SMEs. Yet, high costs of construction including the high cost of labour, material, and equipment, hidden cost (back up, problem-solving and solutions) identified in the research study. Though government provides a fund for construction SMEs, availability of funds and competitiveness in obtaining them are two factors that take into considerations by construction SMEs. However, construction SMEs faced problems due to availability and quality of equipment and material used for their projects. Moreover, respondents highlighted that availability of skilled workers and migration of them to neighbouring countries as a massive threat to the success of the organisations. Furthermore, new construction technologies replace the human works and hence, large construction companies tend to invest in new technologies rather sub-contracting. Thus, construction SMEs even face the issues related to the stability of the organisations.

The demand of bribe by a politician is another biggest threat for construction SMEs. Thus, in some instances, even though they are eligible to get the job, they will not be getting the job due to the corruption in the industry. Hence, there is a high impact for construction SMEs from legal and political threats in the industry. Due to the monopoly created by large construction companies, there is a deficiency in the construction industry. Hence, to retain in the marketplace, there is a huge competition within construction SMEs. This is marked as the prevalent threat for construction SMEs as per the eyes of the respondents. Hence, it is difficult to find clients and access to international markets. Nature/ inherent features of the construction industry marked negative attitudes towards SMEs stability. Yet, unfavourable weather conditions and changing environment influences the success of construction SMEs in Sri Lanka.

4.5. SWOT ANALYSIS MATRIX FOR CONSTRUCTION SMES

Figure 1 represent the SWOT analysis prepared for construction SMEs in Sri Lanka. The above discussed Strengths, Weaknesses, Opportunities and Threats were given in codes in the following figure.

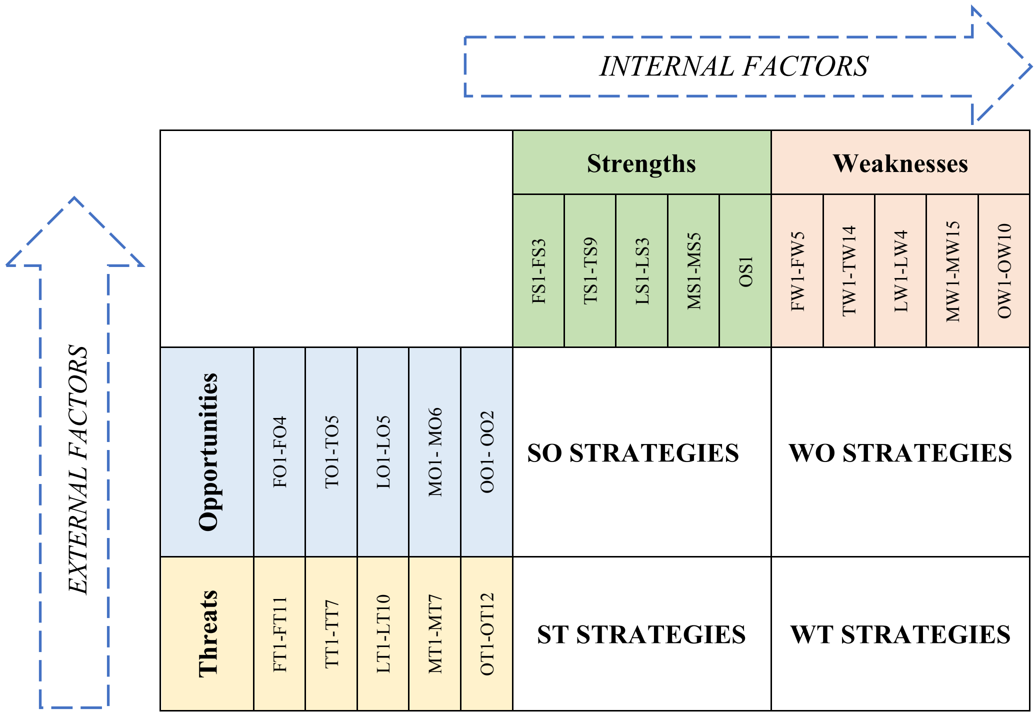

Figure 1: SWOT Matrix for Construction SMEs

The SWOT analysis conducted for construction SMEs depicted that there are internal factors as well as external factors to be considered to sustain in the market. SWOT analysis is a tool for assessing and communicating the current position of an organisation or a particular reform option in terms of its internal strengths and weakness and the external opportunities and threats it faces. The SWOT analysis of the research depicts that, the weaknesses and threats are higher than the strengths and available opportunities of construction SMEs. The SWOT analysis matrix (Figure 1) gives the idea of strategic direction consisted of four possible scenarios to gain the advantage of positive facts over negative facts as SO, WO, ST and WT. Correspondingly, SO is the usage of strengths to make use of the opportunities and WO emphasized on how to take advantage of opportunities by overcoming weaknesses. ST strategies will use strengths to minimise threats and WT strategies will minimise the effect of weaknesses and overcome the threats.

5. CONCLUSIONS

SWOT analysis or categorizing issues into strengths, weaknesses, opportunities, and threats is one of the most respected and prevalent tools for strategic planning (Glaister and Falshaw, 1999; Helms, *et al*., 2011). Usually, it is an effective way of gathering and classifying information, illustrating particular matters, and generating strategic planning ideas for a business (Chan, 2011). Hence, this paper explored the strengths, weaknesses, opportunities, and threats of SME contractors in Sri Lanka. A literature review followed by five case studies were carried out to collect data. The collected data were analysed and presented them in a SWOT analysis to identify the advantage of positive facts over negative facts for construction SMEs.

The findings highlighted that the weaknesses and threats are higher than the strengths and available opportunities of construction SMEs. However, most of the weaknesses identified are controllable with the proper usage of opportunities in the industry. Hence, as per the SWOT matrix, there is a need to explore the SO, WO, ST and WT strategies to gain the advantage of positive facts over negative facts. This study further proves that a detailed understanding of the processes and extensive explorations of all possible causes, reasons using the SWOT analysis will reduce the number of challenges faced by construction SMEs. In addition, it was also evident that inexpensive or zero cost solutions could be implemented by identifying the strengths and opportunities of their organisations. Hence, construction SMEs in Sri Lanka needs to find a way to overcome the controllable challenges. This will pave the way for further research of this study to study the possible SO, WO, ST and WT strategies for construction SMEs. Some respondents already expressed their willingness to implement new construction methodologies and tools in their organisations. Yet, the research findings evidenced lack of new knowledge on the process improvement tools considered as a major constraint against enabling among SME contractors in Sri Lanka.

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ACCESSIBILITY OF EMERGENCY EVACUATION FOR DIFFERENTLY-ABLED PEOPLE IN PUBLIC HOSPITAL BUILDINGS IN SRI LANKA: THE NATIONAL POLICY ENHANCEMENTS

S. Manoj, Harshini Mallawaarachchi*, S.D.A. Soorige and Nimesha Jayasena

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

It is very difficult task in nature and a prevailing issue in the world today to provide a reasonable access for differently abled people within any building. Specially, giving fair and impartial accessibility has become very complex and an ongoing global issue. However, various policies and guidelines have been developed in countries enabling buildings to be used by the differently abled people by building them in terms of ease of access for emergency evacuation. Among the other buildings, healthcare facility has obtained the first concern when considering its' heavy use by differently abled people. Thus, this research was conducted with the purpose of studying on the accessibility procedures of emergency evacuation for the differently abled people in public buildings with special emphasis to public hospitals since the current evacuation means in healthcare sector are not adequately developed based on the needs of differently abled people. The research was conducted using case study method under qualitative phenomenon. Semi-structured interviews were conducted among building professionals who had more than five years of experience in the field of accessibility to collect the data. Hence, three public hospital buildings in Sri Lanka were selected. Accessibility procedures of emergency evacuation and issues in existing practice were investigated related to safety and security, access to built environment and access to communication in line with the National Policy on Disability for Sri Lanka. Case study data revealed that not having predetermined procedure for evacuating differently abled people and less awareness on existing safety and security procedures thus need special attention. Accordingly, a framework was developed to propose the probable enhancements for the national policy. The enhanced policy can be used as a national strategy to assure the ease of accessibility of emergency evacuation for differently abled people in public hospital buildings in Sri Lanka.

Keywords: *Accessibility; Differently-abled People; Emergency Evacuation; Public Hospital Buildings; Sri Lanka.*

1. INTRODUCTION

Over the recent years more importance has been given to improve the ease access of buildings for differently abled people. Further, more technologies have also evolved over the recent years whereas disability is increasingly understood as a human rights issue (Ministry of Social Services and Social Welfare, 1996). It shows that a great deal of work has been done for the improvement of accessibility of buildings for differently abled people (Castell, 2014). Further to author, giving fair and impartial accessibility to buildings for the differently abled people has become very complex and it is an ongoing global issue. The reason for this is the scope of controlling the legislation and standardising buildings varies according to each country. On many occasions the needs of differently abled people are viewed separately from other groups of people and often after the design of a building has been completed (Department for Communities and Local Government, 2006). The Government in many parts of the world have realised the need to identify people with a disability to help by developing the policies and programs for them (Widdowson, 1997). For an example, any new building which is going to be used as a public facility should have an arrangement to provide a better accessibility to differently abled people (Americans with Disabilities Act Title II Regulations, 2010). Further, as another approach developed by most of the countries, all the public places and public buildings which are enabled to

*Corresponding Author: E-mail – hmallawarachchi@gmail.com

use by the differently able people have been regulated to build them in terms of ease of access for emergency evacuation.

However, the current evacuation means in healthcare sector fails to consider the needs of differently abled people in an emergency situation. Similarly, in Sri Lanka, a little attention has been paid on facilitating ease of access to differently abled people in public sector hospital buildings especially in case of emergencies. Thus, there is a vital necessity of studying on current setting of the accessibility of emergency evacuation for the differently abled people in public buildings with special emphasis to hospital buildings in Sri Lanka. Hence, this research was aimed to answer the research question developed "How to enhance the accessibility procedure of emergency evacuation for the differently abled people in public hospital buildings?" The investigation was led to propose probable enhancements for the 'National Policy on Disability for Sri Lanka'. However, the research was limited to conduct a generic investigation on the public hospital buildings in Sri Lanka which facilitate a longer-term care for patients.

2. LITERATURE REVIEW

Disability is an important development issue with an increasing body of evidence showing that persons with disabilities experience worse socio-economic outcomes and poverty than persons without disabilities (Ministry of Social Services and Social Welfare, 1996). According to a study by Prideaux and Roulstone (2009), disability is a kind of bodily deficiency which prevents the person from doing day-to-day activity for the common people. As Prideaux and Roulstone (2009) and Snook and Oliver (2015) further stated, there is an egret need to create living environments suited for differently abled people persons with disabilities live in all parts of the word and at all levels in every society, and their number is on the increase due to various reasons. Today, it is estimated that over 600 million people or more than 10% of the total global population are suffering or affected by some form of disability. Out of them, nearly 400 million people are living in developing countries (Kanter, 2003). Currently it is roughly 650 million people (Rico, 2015). In Sri Lanka, the total of disabled persons is suffering from any form of disability is at 10%, as estimated in a survey conducted in 2013. The prediction of increase in number of disable persons is up to 24.2% at the year of 2040 in Sri Lanka (Ministry of Health, 2014).

The term access can be explained as suitability of a building or other structure for use by people who have disabilities (Widdowson, 1997). In a broader sense, access also includes making forms and information accessible to people with visual or cognitive disabilities; making alarms and signals to people who have hearing impairment and making services such as education and transport accessible to people who have disabilities" (Ministry of Health, 2014). However, it is very difficult task in nature and current problem of the world to provide reasonable access for disabled people within the building which varies country to country and level of their acceptance with aim of the monitoring the legislation and building standards (Castell, 2008). Over the recent years more importance has been given to improve the ease access of buildings for differently abled people, more technologies have also evolved over the recent years. It shows that a great deal of work has been done for the improvement of accessibility of buildings for differently abled people (Castell, 2014). The reason for this is the scope of controlling the legislation and mechanisms used in buildings varies according to each country. According to Americans with Disabilities Act, it requires that government, possessor of the space, service provider, worker or school should provide "reasonable accommodation" to use egress for disabled people (Americans with Disabilities Act Title II Regulations, 2010). The access requirements of differently abled people have been taken into account in recent years. On many occasions, the needs of differently abled people are viewed separately from other groups of people, especially more often after the design of a building has been completed. As the examples, the separation of facilities, such as platform lifts or ramps for wheelchair users located on one side of a stepped entrance can be highlighted (Department for Communities and Local Government, 2006). Further, making such special featured public spaces and the facilities provide an easy access to the building for differently abled people as a built in feature of the environment is good for everyone (Rabinowitz, n.d.).

However, a United Nations survey of 114 countries in 2005 found that many countries had policies on accessibility, but they were unable to found much progress. Of those countries,

- 54% reported no accessibility standards for outdoor environments and streets,
- 43% had none for public buildings,
- 44% had blank for schools, health facilities, and other public service buildings.

- 65% had not initiated any educational programmes,
- 58% had not allocated any financial resources to accessibility,
- 44% of the countries had a government body responsible for monitoring and controlling accessibility for people with disabilities (World Health Organization, 2011).

Indeed, facilitating required access for differently abled people in case of an emergency is another requirement which needs to be considered in designing or modifying buildings (Americans with Disabilities Act Title II Regulations, 2010). According to a study by Kisko and Francis (1985), "emergency evacuation is the process of removing the occupants of a building from a potentially dangerous location to a place of safety (Kisko & Francis, 1985). The emergency plan is very much important in safeguarding life of occupiers. It protects not only the differently abled people but also all other stakeholders within the building (National Fire Protection Association, 2016). For many years, the Disability Movement in Sri Lanka has been requesting from the Government for a National Policy on Disability (Ministry of Social Services and Social Welfare, 2003). A national policy for differently abled people was introduced and was accepted by the cabinet in August 2003. Lack of a clear policy that enables them to exercise their rights and responsibilities, guarantees for them an equitable share of available resources and includes them in the socio-economic mainstream has, up to now, led to programmes with poor sustainability. These in turn have had nil or negligible impact on their situation (Ministry of Social Services and Social Welfare, 2003). The classification of types of disability used by the Ministry of Social Welfare for programme development encompasses people who have visual, speech, hearing, mobility, intellectual, and psychiatric disability and disability arising as a result of epilepsy and other causes. It also encompasses multiple disabilities, which is a combination of two or more of these various disabilities in a single individual. According to that, their socio-economic needs have considered such as, employment, education, housing, use of public services, social security, access to the build environment, access to communication and information (Ministry of Social Services and Social Welfare, 2003). Further, since 2006, the government took a revolutionary decision through which all the public places and public buildings are enabled to use by the disabled people under the Disabled Person's Accessibility Regulation 1 of 2006. All the constructed public buildings and public places are enabled to use by them within a three years' period according to Section 2 of above regulation. Although it was started to implement since 2006, the suitable facilities for the disabled people are not integrated within the most of the public buildings until now (Jayawardena, 2015). Hence, determining probable enhancements of existing regulations pertaining to accessibility for differently abled people in public buildings was identified as an urgent and important requirement to be fulfilled. By reviewing key literature, three major categories of accessibility procedures such as, (i) Safety and security, (ii) Access to built environment and (iii) Access to communication were encountered and used in subsequent analysis. Figure 1 presents the conceptual framework developed.

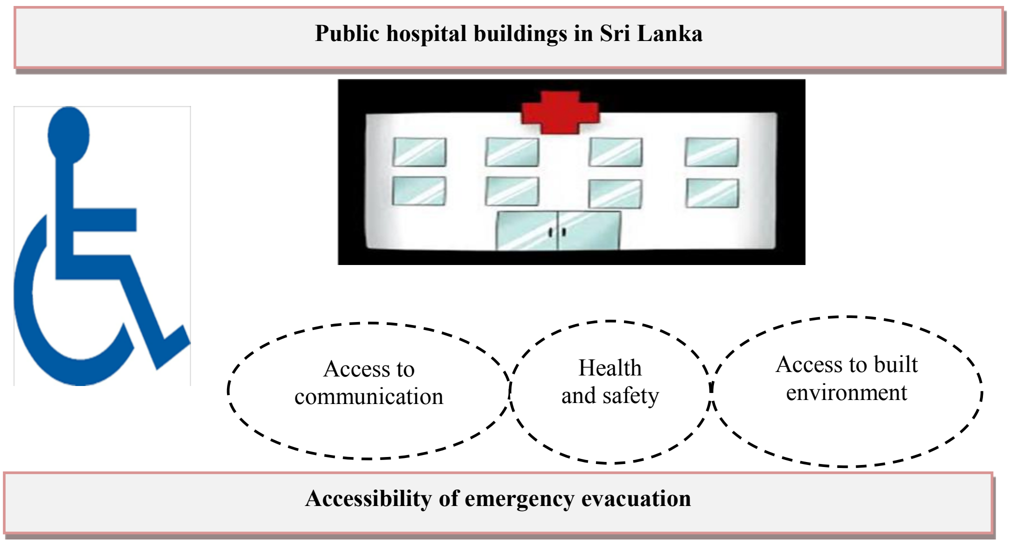

Figure 1: The Conceptual Framework

Section 3 describes the research methodology adopted to identify existing procedures and issues in accessibility of emergency evacuation in public hospital buildings in Sri Lanka.

3. RESEARCH METHODOLOGY

The research was initiated with a literature synthesis for describing the need of the accessibility of the emergency evacuation for differently abled people in public buildings. Since in this research, the current accessibility procedures and related issues were to be investigated, case study method under qualitative approach was found more suitable. Case study is a type of qualitative research approach used when an in-depth investigation of an issue is required (Yin, 2009). Further to authors, by considering the high degree of certainty and validity exist in multiple case study designs, the multiple case study design was used. Three public hospitals in Sri Lanka which provide longer-term care for patients were selected as the cases. The organisation was considered as unit of analysis in each case when studying on the accessibility procedures. Further, a generic investigation was done by considering the accessibility guidelines of the overall hospital building wherein a little attention was paid on separate procedures of individual care units of the hospital.

Direct observations and semi-structured interviews techniques were used to collect the data. According to Yin (2009), interview is one of most important sources of case study information where which appears to be guided conversations rather than structured queries. Thus, nine (09) semi-structured interviews were conducted by selecting three (03) building professionals who had knowledge and more than five (05) years of experience in each case. Table 1 shows the profile of case study interviews.

Table 1: Profile of Interviewees

Case	Designation	Years of Experience
Case A	Fire and safety officer	18
	Engineer	13
	Quality assurance executive	07
Case B	Engineer	16
	Facility manager	05
	Quality assurance executive	03
Case C	Facility manager	08
	Fire and safety officer	07
	Engineer	06

The interview guideline consists of four sections namely Sections A, B, C and D as follows;

- Section A: General information and personal profile
- Section B: Existing accessibility procedures for emergency evacuation
- Section C: Issues in the current practice
- Section D: Strategies to overcome the identified issues

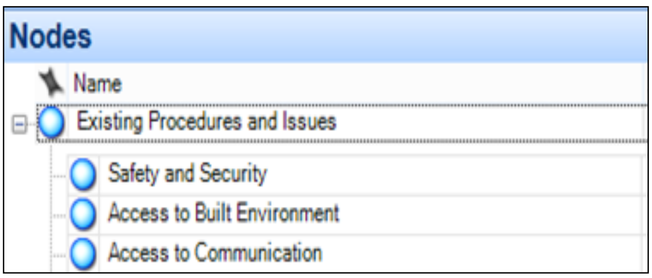

Figure 2: Coding Structure

The data collected through semi-structured interviews in each case were analysed by using cross case analysis techniques as this research contains three cases. According to Yin (2009), cross case analysis is a preferable to apply for the analysis of multiple cases. In analysing the collected data, content analysis technique was used to gather data by codifying qualitative information collected in each case into predetermined categories based on key literature reviewed. QSR.Nvivo 10 software was used in content analysis due to its popularity in similar research setting. Figure 2 illustrates the coding structure developed for case analysis. Next section presents the key research findings of the study.

4. DATA ANALYSIS AND FINDINGS

This section presents key findings of the study broadly on three major headings such as, existing procedures, issues and suggestions on policy enhancements with regards to three areas of safety and security, access to built environment and access to communication as determined in Figure 1.

4.1. SAFETY AND SECURITY

- **Existing procedures**

It is important to consider the safety and security arrangements in the hospital particularly for the differently abled people and patients. According to fire and safety manager in Case A, *"once a patient got operated he is temporarily unable to do his activities so he is considered as a differently abled person and has a need to safe and secure himself."* Thus, various procedures have been implemented within the general system to evacuate the differently abled people in case of an emergency. Locating signboards and floor plans, implementing emergency preparedness programme and locating care unit at each floor can be identified as existing means. As quality assurance executive in Case B stated, *"each wing of the floor has a care unit. It is especially beneficial for the differently abled people and patients as they can easily access without any problems. Staffs in those care units will take the responsibility to handle the patients as well as visitors in emergency situations."* However, as there is no specific procedure adopted for differently abled people, several issues prevail within existing practice can be identified.

- **Issues**

The empirical data of case studies indicated several issues relating to safety and security in public hospital buildings in terms of accessibility for differently abled people. Not having fire lift to use in emergency situations and not facilitating emergency call points for patients were identified as major issues existed in three cases selected. This has become a critical issue specially when evacuating differently abled people in case of any emergency. Statement of quality assurance executive in Case B that "*if fire catches on the top floor and unfortunately differently abled people got into the side and will be a problem for them to exit, so in case of such problems always difficult to evacuate those differently abled people and according to the standard operational procedures there are only ways to carry them outside by means of manually but no other facilities*" shows importance of such. Further, in most of the emergencies, differently abled people have been evacuated manually as there is no fire lift, no predetermined procedure or an accessibility guideline for differently abled people in selected organizations. Another issue highlighted was the less awareness on existing safety and security procedures by both patients and officials. As stated by engineer in Case A that "*generally most of the people do not follow the signs and it will create many turmoil for them as well as the officials too.*" Accordingly, several procedural issues can be identified such as not having fire lift to use in emergency situations, not facilitating emergency call points for patients, no predetermined procedure or an accessibility guideline for differently abled people and less awareness on existing safety and security procedures by both patients and officials, which should be conversed with national policy enhancements.

- **Suggestions for policy enhancements**

In order to mitigate the issues existed in safety and security procedures, several attributes can be suggested for enhancing the policy. Each hospital should adopt a new procedure which contains special needs of differently abled people and should prioritize them in times of emergency. Further, as case respondents proposed, proper arrangements and placement of fire lift and provision for a band system to easily identify the conditions of each differently abled people can also be implemented in public hospital buildings for easy of accessibility in case of an emergency. Facility manager in Case C stated that *"We have faced lots of issues when evacuating differently abled people during emergencies without having a proper accessibility plan. So, proper arrangements and placement of fire lift will be important to evacuate them easily and without any harm"* shows the importance of proposing such. Further, installing emergency call point beside every patient's bed will be helpful for ease of evacuation, as stated by most of case respondents.

Hence, the existing accessibility procedures available for safety and security in national policy can be enhanced by adopting a new procedure which contains special needs of differently abled people, prioritizing the needs of differently abled people in times of emergency, proper arrangements and placement of fire lift, installing emergency call point beside every patient's bed and adding provisions for a band system to easily identify the conditions of each differently abled people.

4.2. ACCESS TO BUILT ENVIRONMENT

- **Existing procedures**

There are several accesses to the building. Are they effectively being used in emergency situations? This is a serious problem in many buildings. Findings also revealed that most of the public hospital buildings in Sri Lanka are having general circulation path including lot of emergency access other than any special evacuation ways specially arranged for differently abled people. As stated by engineer in Case B, "*we don't have any special evacuation ways specially arranged for differently abled people. They have to use the normal evacuation routes as all others."* Facility manager in Case C also verified that "*there are lot of ways have been identified for emergency evacuation in this building such as, lifts, elevators, ramps, fire exit, fire doors, staircase footpaths and corridors."*

However, not having proper guideline for accessibility for differently abled people has led to several issues as described subsequently.

- **Issues**

The absence of a fire lift in the building and not using directional tactile tiles were identified as major issues existed in current procedures. Directional tactile tiles help the blind people to identify the pathways. Facility manager in Case C said that "there *is no any fire lift in the hospital and further there are no any tactile tiles placed in the building."* Further, there is no any announcing system which announces the floor number inside the lift during operation. This was also identified as another major drawback by most of respondents.

Accordingly, not using directional tactile tiles, absence of a fire lift and not having proper announcing system were recognised as major issues related to built environment which need to be considered in national policy enhancements.

- **Suggestions for policy enhancements**

While lot of emergency accesses are available within public hospital buildings in Sri Lanka, the effective use of those was proposed to encourage within the national policy. Hence, providing sufficient awareness and training for internal employees on how to evacuate differently abled people, adopting special needs of differently abled people into the emergency preparedness programme or having a specific programme for differently abled people were highlighted by most of the case respondents. As proposed by quality assurance executive in Case A, *even though we have lots of emergency access to built environment, no one knows what the correct and right way to use them is. Therefore, providing proper training for staff and for specially appointed evacuation team would be beneficial."* Furthermore, installing directional tactile tiles is also mentioned as an important provision to include in the national policy to guide visually impaired people along a route with ease of access to built environment.

Hence, new provisions for an effective use of emergency accesses, providing sufficient awareness and training on how to evacuate differently abled people, introducing a specific programme for differently abled people and installing directional tactile tiles can be conversed in national policy enhancements.

4.3. ACCESS TO COMMUNICATION

- **Existing procedures**

Case study findings divulged that, most of the public hospital buildings are suffering from fewer procedures adopted for access to communication. As the existing strategies available, having public address system and locating signboards can be highlighted. Further, some of hospitals have appointed a specialist from the blind school to support blind people in case of an emergency. As proved by Facility manager in Case B *"whenever there is a problem due to the language barrier especially for the blind people they appointed a specialist from the blind school for their betterment."* Even though the buildings are equipped with public address systems and signboards as the existing strategies, the lack of procedures specifically for differently abled people has generated several issues as described accordingly.

- **Issues**

As common to many buildings, absence of a proper audible system and scarcity of strobe lights are the major drawbacks. *"If any visual notifications like strobe lights are available in the hospital, deaf people can alert them from the danger. But unfortunately, hospital does not have such facilities"* said the fire and safety officer in Case C. In Case A, fire and safety manager of the hospital also stated that there is no any special audible system particularly for the deaf people. Further, quality assurance executive in Case B said that *"even though a lot of strategy measures during emergency situations to evacuate the people, there is no any special strategy available for the differently abled people and in case of such danger those differently abled people are protected by manually with the help of existing care unit."* Further, no scrolling reader for supporting deaf people and communication barrier existed between local staff and foreign patients and visitors are the other issues that need to be considered for policy enhancements. Hence, the issues of not having scrolling reader for supporting deaf people, absence of proper audible system and strobe lights and communication barriers existed between local staff and foreign patients and visitors can be considered in national policy enhancements.

- **Suggestions for policy enhancements**

As a key area that needs to be considered in national policy enhancements, introducing provisions for ensuring 'access to communication' can be suggested. As depending on the traditional alarm system alone could generate several issues, hospital accessibility procedures can be introduced with special strategies for differently abled people such as, VADs (Visual Alarm Devices - flashing beacons) etc. Another enhancement that can be proposed through policy is providing provisions for installing strobe lights, emergency scrolling readers and other tactile devices such as pagers or vibrating pillows or beds etc. As stated by facility manager in Case C *"Scarcity of visual notification systems is a major issue in our building. Thus, making provisions for providing such facilities would be important"*. As case respondents proposed installing VADs (visual alarm devices - flashing beacons) and other tactile devices such as pagers or vibrating pillows or beds can be facilitated in hospital buildings for ease of use by differently abled people in emergency situations.

5. DISCUSSION

According to the case study data, the existing procedures and issues in accessibility procedures of emergency evacuation for differently abled people in public hospital buildings in terms of health and safety, access to built environment and access to communication should have special attention in national policy enhancements. Empirical findings revealed that absence of fire lift to use in emergency situations, not facilitating emergency call points for patients, not having predetermined procedure or an accessibility guideline for differently abled people and less awareness on existing safety and security procedures by both patients and officials could increase the threat on differently abled people in case of an emergency. Thus, a special attention can be paid in national policy enhancement. Experts also expressed that, absence of a fire lift, no use of directional tactile tiles and absence of proper announcing system for lifts located can be highlighted as other accessibility related issues existed in current practice. Nevertheless, access to communication also needs special attention in the process of policy enhancement, as the current practice prevails several issues such as, absence of a proper audible system, scarcity of strobe lights, no scrolling reader for supporting deaf people and communication barriers existed between local staff and foreign patients and visitors specially in case of an emergency. The summary of key issues identified in case analysis are presented in Table 2.

As empirical data revealed, not having a predetermined procedure or an accessibility guideline for differently abled people and less awareness and training on evacuation of differently abled people in case of an emergency were the critical issues existed in public hospital buildings. Hence, the specialised modern technologies can be introduced within public hospital buildings to overcome the accessibility issues. Accordingly, as the key findings derived through case analysis, probable enhancements were proposed to overcome the identified issues in existing procedures.

Table 2: Summary of Key Issues in Accessibility Procedures

Major category	Issues in existing procedures
Safety and security	▪ Not having fire lift to use in emergency situations ▪ Not facilitating emergency call points for patients ▪ No predetermined procedure or an accessibility guideline for differently abled people ▪ Less awareness on existing safety and security procedures by both patients and officials
Access to built environment	▪ Not using directional tactile tiles ▪ Not having proper announcing system
Access to communication	▪ Absence of a proper audible system ▪ Scarcity of strobe lights ▪ No scrolling reader for supporting deaf people ▪ Communication barrier existed between local staff and foreign patients and visitors

The opinions of experts in the field and the secondary data divulge key attributes for enhancing the National Policy on Disability for Sri Lanka as indicated below,

- A major section can be introduced for accessibility of emergency evacuation for differently abled people in public buildings
- The major section can be added with accessibility rules and regulations which are mainly related to safety and security, access to built environment and access to communication.
- The provisions of safety and security may include; adopting new procedure which contains special needs of differently abled people, prioritize differently abled people in times of emergency, making proper arrangements and placement of fire lift, introducing provision for a band system to easily identify the conditions of each differently abled people and installing emergency call point beside every patient's bed.
- Access to built environment can be added with new provisions including, providing sufficient awareness and training on how to evacuate differently abled people, adopting the special needs of differently abled people into the preparedness programme or having a specific programme and installing directional tactile tiles for guiding differently abled people with clear directions specially in case of an emergency.
- Further, installing Visual Alarm Devices (VADs), installing emergency scrolling readers and other tactile devices such as pagers or vibrating pillows or beds can be noted under 'access to communication' in the process of national policy enhancements.

The summary of strategies deemed in the developed framework (Figure 3) can be used to enhance the National Policy for Disability in Sri Lanka.

The enhanced policy can be used as a basis to evaluate the current practice of public hospital buildings in Sri Lanka. Indeed, the national policy can be introduced with proposed enhancements to facilitate a reasonable access for differently abled people in public hospital buildings in case of an emergency.

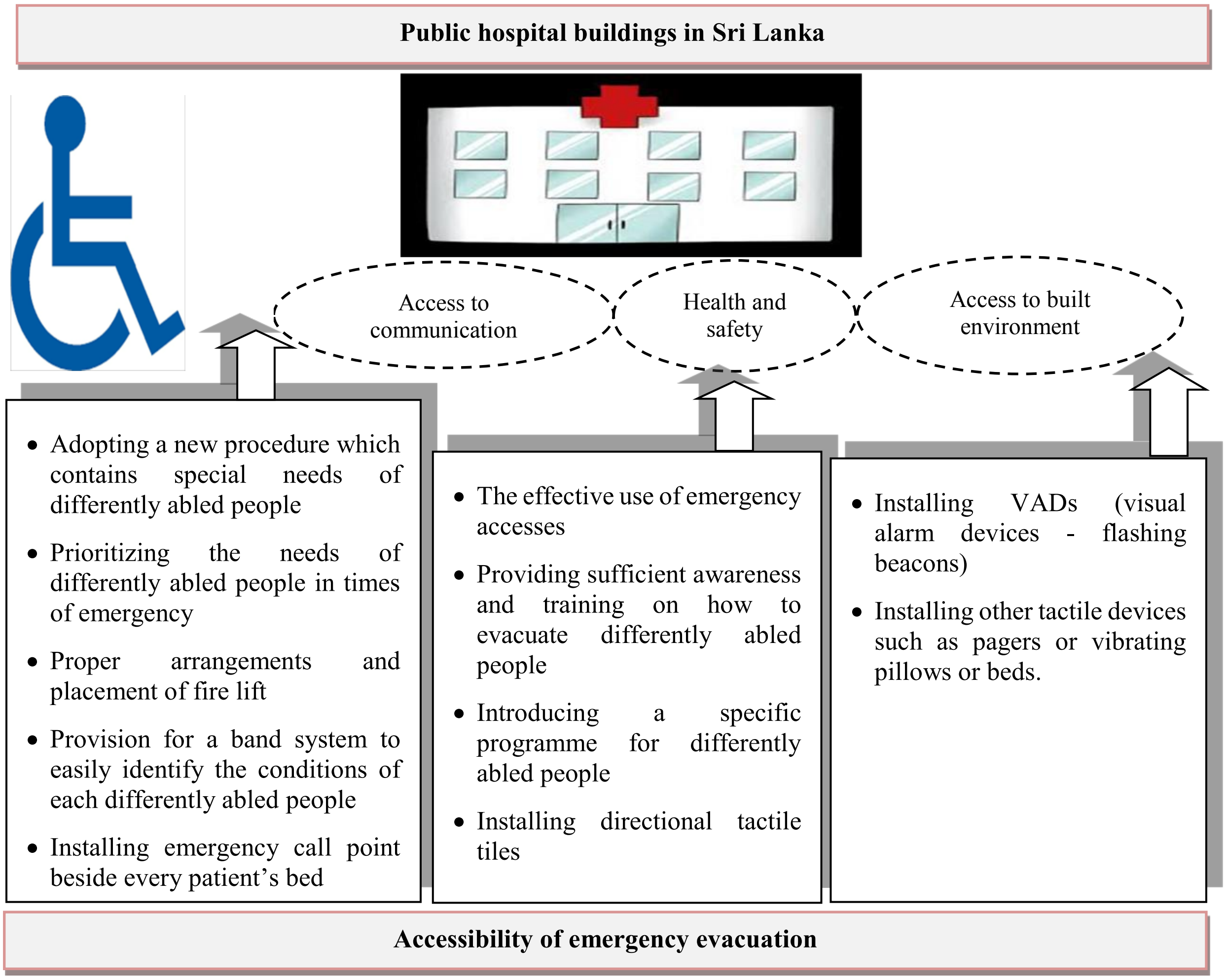

Figure 3: Suggestions for Enhancements

6. SUMMARY

By considering the necessity had on studying accessibility of emergency evacuation for the differently abled people in public buildings in any unfavourable environment, this research was conducted in this respect while a special attention was given to public hospitals. The reason behind the selection of public hospital buildings is justified by the current means of evacuation which were existed in healthcare sector fail to necessitate the need of differently abled people. As findings revealed, several issues were identified in existing practice related to safety and security, access to built environment and access to communication. Thus, developing special plans and strategies to help the differently abled people and adopting their special needs into existing means of evacuation would be fruitful as it may definitely aid their survival in times of emergency. As the main implication of the study, probable enhancements for the National Policy on Disability for Sri Lanka were proposed through a framework to overcome the accessibility issues in public hospital buildings in Sri Lanka. Thus, the enhanced policy can be preceded as a national strategy to assure the proper evacuation of differently abled people during emergencies in public hospital buildings with easy accessibility undeniably.

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ADAPTABILITY OF SHARED WORKSPACE CONCEPT IN OFFICE BUILDINGS IN SRI LANKA

W.Y. Perera*, B.A.K.S. Perera and T.S. Jayawickrama

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

A well-organised, well-designed workspace in an organization will help it to fully achieve its goals. Although visiting staff are also considered as staff of an organisation, they often face difficulties in finding space within the organization for working as they are not generally assigned specific workspace to work from. In Sri Lanka, many office buildings have unutilised floor space. These unutilised spaces are quite costly to maintain. Moreover, an unutilized space will have an adverse impact on the sustainability of the organisation. This study addresses these issues by investigating the adaptability of shared workspace concept in office buildings in Sri Lanka. To achieve this aim, a literature review, 14 expert interviews and two case studies were conducted. Content analysis was used to analyse the findings. The study identifies the type of office spaces that can be used as shared workspaces. It is found that not all offices with unutilised space will be able to decide to adopt the shared workspace concept as that decision has to be based on the type and operating hours of the office, core business of the organisation, organisational culture and the support structure and the accessibility of the building in which the office is housed.

Keywords: *Co-working; Flexible Spaces; Office Buildings; Shared Workspace; Sustainable Facilities.*

1. INTRODUCTION

Many industries and sectors are now making a shift towards an increasingly complex, unpredictable and dynamic knowledge environment (Saurin *et al*., 2008). According to Laterveer (2011) and Ketting (2014), different individuals have different needs for space and they can rent out the space they require for a day, a month, a year etc. With the advent of the new millennium, workplaces have become fluid and multi-layered with their boundaries blurring (Saurin *et al*., 2008). Calder and Courtney (1992) believe that market trends have created a new paradigm in office space usage. In the ever changing global and competitive business world, it is necessary to be able to adapt to change both as an organisation and as an individual to achieve one's business goals (Bridges, 2009). When leasing a building for use as an office in a market that requires constant changes, it is desirable to have flexibility in the duration of the building lease, use of services and choice of space (Gibson and Lizieri, 1999). The increasing number of self-employed workers, and other labour market trends such as the growth in the use of technologies and the decrease in the amount of workspace allocated to individuals have also influenced the use of office space (Green, 2014; De Vries and Van de Besselaar, 2013).

Until the turn of the century, most white-collar workers remained securely bound to their office desks simply because they could have all the tools they required for their jobs available in one single place close to their desks (Felstead *et al*., 2003). The space they required consisted of the space they needed for their jobs as well as storage space, meeting rooms, communal areas and equipment space (Brooks, 1998). Today, working practices of many organisations have made this requirement to change (Fawcett, 2009). Not all employees today will need permanent space for their work. Van Zutphen *et al*. (2015) have described a new way of working called flexible working which allows the workers to have their own work schedules and work from a location of their choice without requiring expensive space to work from.

*Corresponding Author: E-mail – yas.pera@gmail.com

Waber *et al*. (2014) defines shared workspace/co-working space as a membership-based workspace where diverse groups work together in a shared, communal setting. According to International Facility Management Association (IFMA) (2016), headcount has always been a challenge to organizations when the space available becomes insufficient to accommodate the uncalculated labour, with staff except full-time staff having no assigned workspace. Although these employees account for only 10% of the total workforce, 90 % of the time and effort of the organization is spent in finding space for them. There are spaces in offices which are not being effectively utilized because of planning failures and other reasons and there are costs involved in their maintenance.

There have been studies done in the past on areas related to this concept. For example, Duffy (2000) and Harrison *et al*. (2014) have studied the number of workstations that have to be provided for a given number of flexibly working employees, known sometimes as workstation-sharing ratio. Fawcett and Rigby (2009) have reported on using a simulation model to explore workstation sharing in a probabilistic way. Laing (1990) did studies on desk sharing. Leclercq-Vandelannoitte and Isaac (2016) have studied co-working/ shared work spaces in detail along with the issues which the concept has with other areas. However, it was found that there is a research gap between the adoption of the concept in office buildings and sharing the office space with outsiders.

The concept of shared workspace is still new to Sri Lanka. However, it is now gradually gaining popularity because of its ability to cater to the space needs of short term contracts. This study therefore aimed to look at the adaptability of the shared workspace concept in organizations in Sri Lanka that have unutilized space or are short of space for its non-permanent workers. The focus of the study was on converting unutilized spaces in offices located in Sri Lanka into shared workspaces that can accommodate non-permanent staff or the outside community. The objectives of the study were to make an in-depth study of the shared workspace concept and to identify the requirements that exist for shared workspaces in office buildings, the spaces in offices that can be used as shared workspaces and the characteristics an office building needs to possess if it is to successfully adopt the shared workspace concept.

2. LITERATURE REVIEW

2.1. SHARED WORKSPACES

Attitudes towards consumption have shifted in recent years resulting in increasing concerns over ecological, societal, and developmental impacts of consumption (Albinsson & Perera, 2012). A recent major evolution has reshaped the capitalist economy (Goudin, 2016). Transition from the traditional individual ownership of assets to accessibility-based models is present in a wide range of markets (Goudin, 2016). Belk (2007) defined sharing as the act and process of distributing to others for their use what is ours and the act or process of receiving or taking something for our use from others.

Today, there are many who prefer to work independently in a flexible work environment making use of information technologies. Three kinds of shared spaces exist: physically shared spaces, technically shared spaces, and cognitively shared spaces (Bhatt et al., 2014).

Co-working takes place in shared, collaborative workspaces in which the emphasis is on community (not space), relationships, and productivity. It is a new form of working in which workers from different companies or freelancers with different profiles and objectives work as a community within a shared space (Johns and Gratton, 2013). Leclercq-Vandelannoitte and Isaac (2016) consider teleworking or remote or mobile working as the earlier versions of co-working. Waber, Magnolfi and Lindsay (2014) are of the view that the concept of co-working is a result of the drawbacks of remote working and excess virtualisation of people and organisations. Co-working spaces are utilised by different categories of professionals, mostly freelancers, who have various degrees of specialisations (Gandini, 2015). Kwiatkowski and Buczynski (2011) have stated that shared or co working spaces which are the foundation of the freelance/self-employed realm have now expanded into small and moderate sized businesses too. Co-working spaces are creative and energetic and people can interact, share, build and co-create in these spaces (Fuzi, 2015).

The characteristics expected of shared workspace users have so far failed to receive much attention. Each user has his or her own geographical characteristics (e.g., residential, city or village), demographic characteristics (e.g., age, gender, income and level of education), psychographic characteristics (e.g., interests, activities and values) and behavioural characteristics (e.g. brand loyalty, readiness to buy or degree of loyalty) (Kotler, 1994).

2.2. OFFICE BUILDINGS

According to Building Owners and Managers Association, there are three classes of office buildings: Class A buildings are prestigious buildings which have the highest quality as office space with high-quality finishes, state of the art systems and exceptional accessibility and with rents standing above the average for the area. Class B building rents are higher than the average rent in the area: their building finishes are better in comparison to those of other buildings in the area and their systems are adequate. However, these buildings cannot compete with Class A buildings of the same price. Class C buildings attract tenants requiring functional space at rents below what is average in the area.

Laing et al. (1998) have identified, based on the number of contacts required among office workers and the level of their autonomy, four main types of offices: Hive, Den, Cell and Club. There are many different office layouts also, varying from traditional private office layouts to open office layouts. Even open offices have a major diversification (Sanders & McCormick, 1993). Brill et al. (2001) have defined the private cellular office as a workspace that has a door and four walls rising up to the ceiling and the open plan office as a workspace whose perimeter boundaries do not rise up to the ceiling. Charles et al. (2004) have stated that office layouts can influence employee satisfaction and the attitudes, behaviours and commitments of the employees. A change in the physical settings of an organisation will lead to organisational change (Kenreich, 2001).

2.3. OFFICE CULTURES

Culture can be formally defined as the beliefs, values, attitudes, behaviours and practices that are characteristic of a group of people (Warrick, 2015). Organizational cultures are mainly of four types. Hierarchy culture is present in formalised and structured places of work where what employees have to do are governed by procedures (Cameron & Quinn, 2011). Market culture as described in the Organizational Culture Assessment Instrument is found in results-oriented workplaces. Leaders of these cultures are hard driving producers and competitors. They are enthusiastic about market share and penetration (Grudzewski and Hejduk, 2001). In organizations with clan cultures, employees have a sense of being in one family and the more lenient policies adopted by these organisations encourage the employees to personalise their workspaces (Wells *et al*., 2007). Adhocracy culture in an organization will discourage centralised power or authority. Instead, it will let the power to flow from one employee to another or from one job team to another depending on the problem in hand (Grudzewski and Hejduk, 2001).

3. RESEARCH METHODOLOGY

The qualitative research approach considered by Brikci and Green (2007) as the best approach that can be used for collecting opinions and facts from people based on their experience was used in this study to collect the required data. Thus, a series of interviews with experts were conducted to confirm literature review findings and their applicability to Sri Lanka. Since the concept of shared workplace is novel to Sri Lanka, fourteen experts who had more than five years of industry experience were selected using snowball sampling for interviewing. These experts were engaged in either building designing or building operation or were building employers. Only questions related to their areas of specialisation were put to them during the interviews. Two case studies were used to validate interview findings. Semi-structured interviews, observations and document reviews were used during the case studies to collect data. Documents such as records and co-workers' complaints were perused during the case studies to identify the problems associated with the concept. Since the shared workspace concept deals with building space utilisation, observations were used to grasp the cores of the case studies as suggested by Strauss and Corbin (1990). Table 1 presents the profiles of the expert interviewees and Table 2 presents the details of the case studies. Case study interviews were with the managerial staff of the facility concerned and the coordinators of its shared workspace project.

Table 1: Expert Interviewee Profiles

	Profession	Designation	Industry experience
Interviewee A (IA)	Chartered Architect	Senior Lecturer	15 years
Interviewee B (IB)	Chartered Architect	Owner/Managing Director	26 years
Interviewee C (IC)	Chartered Architect	Senior Lecturer	8 years
Interviewee D (ID)	Chartered Architect	Owner/Managing Director	8 years
Interviewee E (IE)	Facilities Manager	Facilities Executive	5 years
Interviewee F (IF)	Chartered Engineer	Premises Project Manager	20 years
Interviewee G (IG)	Business Administration	Operations Manager	25 years
Interviewee H (IH)	Chartered Engineer	Operations and Maintenance Engineer	15 years
Interviewee I (II)	Graduate Engineer	Assistant Facility Manager	6 years
Interviewee J (IJ)	Graduate Engineer	Engineer	5 years
Interviewee K (IK)	Entrepreneur	Owner/Managing Director	5 years
Interviewee L (IL)	Lawyer	Director(Investor)	10 years
Interviewee M (IM)	Economist	Director	8 years
Interviewee N (IN)	Chartered Engineer	Facility Manager	26 years

Table 2: Case Study Details

Description	Case 01 (C01)	Case 02 (C02)
Core business	Marketing	Property development
Experience in sharing workspaces	01 year	08 months
Number of shared spaces available	Meeting rooms - 01 Private office rooms - 04 Open workstations -09	Meeting rooms - 01 Private office cubicles -07 Open workstations - 0
Time available for sharing	Weekly Monthly Semiannually Annually	Quarterly Semiannually Annually
Operating hours	24/7	24/7
Number of floors	2 floors	2 floors
Location	Colombo	Colombo

4. RESEARCH FINDINGS AND ANALYSIS

4.1. *SHARED WORKSPACE CONCEPT*

Table 3 below presents the expert interview findings used to validate the literature findings.

Table 3: Reasons for the Emergence of Shared Workspace Concept

Reasons	Expert Findings	Case 01	Case 02
Drawbacks of remote working and excess visualization (Waber *et al*., 2014; Leclercq-Vandelannoitte and Isaac, 2016)	IA,IC,IE,IF,IG,IH,II,IK,IL,IM	✓	✓
Impacts of knowledge, cognitive and sharing economy (Belk, 2010; Botsman & Rogers, 2010)	IA,IB,IC,IE,IF,IG,IH,II,IK,IL, IM	✓	✓
Low initial investment required	IA,IB,IC,ID,IE,IF,IG,IK,IL	✓	✓
Exposure to integrated facilities	IA,IB,IC,ID,IE,IF,IG,IK,IL	✓	✓
Availability of a decent address for the business	IA,IB,IC,ID,IE,IF,IG,IK,IL	✓	✓
Increasing independence sought by employees	IA,IB,IC,ID,IE,IF,IG,IK,IL	✓	✓

Reasons	Expert Findings	Case 01	Case 02
Increased awareness	IA IC ID IE IF IG IK IL	✓	✓
Poor bonds that exist with the third parties	IC ID IE IF IG IK IL	-	-
Interactions with other parties	IC ID IE IK	✓	✓
Changes in consumer life cycles and expectations	IB	✓	-
Convenience of the work environment	IA	✓	✓

The concept of co-working spaces or shared workspaces emerged because of the drawbacks of remote working and excess visualization. Most of the workers who remotely work from homes may at times need an office for their meetings, daily work, etc. Shared workspaces have come into place to cater to this requirement. The other contributory factor to the concept is the low initial investment it requires for implementation. Start-ups/entrepreneurs/freelancers/co-workers do not possess sufficient capital to invest in an office at the time they begin their businesses even though what they require at that time is only a small space for their business work. If they are willing to make use of shared workspace/co-working space available, they need to invest only very little for working space. They can use this space only at the time they exactly want it by paying rental at an hourly rate (e.g., 500LKR/hour). Integrated facilities such as utilities, data connections, high quality office furniture, interior décor etc., available in shared workplaces and which make the working environment comfortable, also have contributed to the emergence of the concept of shared workspace. Users of these workspaces are unable to have these facilities on their own during the early stages of their businesses. However, most co-workers require only a table and a chair, a decent address and very limited building services. In a shared workspace, the user automatically gets entitled to a decent business address which every organization is in possession. For start-ups, a good business address is always of value.

4.2. SHARED WORKSPACES IN OFFICES

In Sri Lanka, there is so much space that can be used as office space but they lack the characteristics of an office environment. The owner of an office having unoccupied space can always benefit by letting out that space for use as a shared workspace. At a time when owners of office buildings are reluctant to rent out on long term leases unoccupied space in their offices, the shared workspace concept will be an eye opener to them. Table 4 presents the reasons given by the experts during case studies for adopting the shared workspace concept.

Table 4: Reasons for Shared Workspaces in Offices

Factors	Experts' Findings	Validations from cases	
		Case 01	Case 02
Failure to accurately estimate the headcount at the design stage	IA, IB, IC, IL, IE, IF, IG, IH, IK	✓	-
High cost of workspace (Rs./m²)	IA, IB, IC, IL, IE, IF, IG, IH, IK	✓	✓
Income generation	IA, IB, IC, IE, IF, IG, IH, IK, IL	✓	✓
Lack of office space in urban areas (Colombo)	IA, IB, IH, IG, IJ, IH	✓	✓
Not having ownership but only sharing	IA, IB, IC, ID, IK, IL	✓	
Millennials' requirements	IA, IB, IC, ID	✓	✓
Asset sharing/ Resources	IE, IG, IF	✓	✓
Parking and accessibility	IA, IB, IH	-	-
Inadequacy of the existing workspaces for the available workforce	IG, IK	-	-

According to IB, though the concept of shared workspace is novel, most designers consider at as a concept that is sustainable. When constructing an office facility, it will always be challenging to get the correct head count (IFMA, 2016). Therefore, the actual headcount of an office building can often be different from what was estimated during its design stage. There can even be excess space. At the same time, an organization encountering financial difficulties may decide to reduce its labour force which can have a direct impact on the space requirements. The idling space can be rented out without temporarily shutting down the office.

Irrespective of whether all the space in an office is effectively used or not, its overhead costs will always be quite high as especially in urban areas like Colombo, it is costly to maintain space. These overhead costs will therefore depend on the extent to how effectively the space is being utilized. With the adoption of the shared workspace concept, income generation from idling office space will become a reality.

The cost of owning a space will always be greater than the cost of using a shared space. Thus, for a co-worker, a start-up or a freelancer, it will always be more beneficial to use a shared space rather than one's own space.

According to the experts, most buildings do not have facilities expected by their prospective tenants, which increases the demand for space with the required facilities. In Colombo, there is a shortage of office space (Jones Lang LaSalle, 2016).

A business that is growing is expected to address the requirements of millennials as our future workforce will comprise of a higher percentage of millennials. Since they value innovative thinking, shared spaces have become common among them. Therefore, in the years to come, shared spaces will attract more attention. Along with the sharing of unoccupied space of an office building with outsiders, the assets of the office such as printers, air conditioners and machinery can also be shared. Asset sharing is a sustainable activity: it can also optimize the energy usage of the organization. It will also have an impact on the carbon footprint of the organization as if all the start-ups decide to buy printers, air conditioners and machinery for their day to day use then all these will have an impact on the environment and their unwanted emissions will indirectly increase the carbon footprint.

4.3. OFFICE SPACES THAT CAN BE USED AS SHARED WORKSPACES

An organization will have different types of underutilized or unutilized spaces. During the design stage of a building, it is always possible to create a space suitable for multiple purposes. Table 5 presents the type of spaces that can be used as shared workspaces as revealed by the experts and case study findings although some organizations for various reasons may not always want to use these spaces as shared workspaces. In the two cases studied, there were shared workspaces which were already being used by external parties on rent.

Table 5: Office Space that can be Used as Shared Workspace

Type of space	**Experts' Findings**	**Validations from cases**	
		Case 01	**Case 02**
Board room	IA, IB, IC, ID, IE, IF, IG, IH, II, IJ, IK, IL, IM, IN	✓	✓
Meeting rooms	IA, IB, IC, ID, IE, IF, IG, IH, II, IJ, IK, IL, IM, IN	✓	✓
Auditorium	IA, IB, IC, ID, IE, IF, IG, IH, II, IJ, IK, IL, IM, IN	✓	✓
Cubicles	IA, IB, IC, ID, IE, IF, IG, IH, II, IJ, IK, IL, IM, IN	✓	✓
Workstations	IA, IB, IC, ID, IE, IF, IG, IH, II, IJ, IK, IL, IM, IN	✓	✓
Common facilities (washrooms, lobbies cafeterias)	IA, IB, IC, ID, IE, IF, IG, IH, II, IJ, IK, IL, IM, IN	✓	✓
Parking areas	IA, IB, IC, ID, IE, IH, IJ, IK, IN, IM	✓	✓
Resource Room	IC, IE, IK, IJ, IL, IM	✓	✓
Rest Rooms	IA, IB, IC	✓	✓
Private lounge	IB, IE	✓	✓

IB mentioned that space that can be used for multiple purposes can be created when designing a building. He was of the view that there can be many ways of rearranging the space that has been designed only for one particular activity. When an organization shares its space with an external party, it will not be possible to compromise the facilities as the underutilized space is to be provided to the community as a shared workspace. Spaces in the hospitality trade are generally in demand for meetings and for team work. Since during most of the time, meeting rooms, the board room and the auditoriums of an organization are unoccupied, it will be possible to rent them out to an external party during these times. Before deciding to rent out these meeting rooms, board rooms and auditoriums, their frequency of use has to be determined. Organizations will benefit if entire floors can be renovated to create shared spaces.

Workstations are popular globally as shared workspaces. However, the expert interviewees opined that for several reasons it is impractical to share the workstations used by the employees as workstation sharing should not in any way disturb the existing operations of the organization. When organizations rent out space for short periods, areas such as washrooms, lobbies, vehicle parking space, cafeterias etc., also have to be provided to their customers. Some office buildings have their own private lounges where their employees can relax. These lounges can cater to private parties and gatherings as well. Therefore, this type of spaces can also be rented out to external parties for functions during day time. Adjacent offices can make use of unutilized rest rooms if possible. However, the particular office cultures prevailing in some organizations may not permit the sharing of rest rooms with nearby offices. The smooth operation of a shared workspace can be ensured by centralising it for ease of monitoring and controlling.

4.4. CHARACTERISTICS OF AN OFFICE THAT CAN ADOPT THE SHARED WORKSPACE CONCEPT

An organization planning to adopt the shared workspace concept should have certain characteristics. These characteristics were identified from expert and case study interviews and validations. Table 6 presents these characteristics all of which are focussed on the office building and user requirements.

Table 6: Characteristics of an Office that can adopt the Shared Workspace Concept

Characteristics	**Expert interview findings**	**Validations from the cases**	
		Case 01	**Case 02**
Office class			
▪ Class B	ID,IH,II,IK,IL,IM	✓	✓
▪ Class C	ID,IH,II,IK,IL,IM	✓	✓
Type of office			
▪ Cell	IA,IC,ID,IF,II,IK	✓	✓
▪ Den	IA,IC,ID,IE,IF,IG,IH,II,IK,IL	✓	✓
Type of culture			
▪ Task	ID,IE,IF,IG,IH,IL,II,IK	✓	✓
▪ Person	ID,IF,IF,IH,II,IL	-	-
24/7 operations		✓	✓
Support structure to facilitate the users	IA,IC,ID,IF,IG,IH,II,IN	✓	✓
Accessibility	-	✓	✓

A client will always want to verify the class of a building before renting it out as the building class can provide useful information about the building. Shared workspace users have their own minimum requirements for their work environments. Thus, a Class B or a Class C building will always be more acceptable to them than a Class A building since the rental of the latter will be too high for them. IF endorsed this by stating that often reputed organisations having unoccupied space that can be used as shared workspace are generally not willing to give their space to outside communities as it can affect the comfort of their employees

A shared workspace of an organization has to be accessible to its users throughout the day and the employees of the organization should be careful enough to not to disturb the co-workers. Customer friendly office buildings will not be suitable for sharing. Similarly, sharing of a place that has limited office space designed for repetitive tasks will be difficult. Cell and Den offices are more suitable for sharing. In a cell type office, there will be many workstations used in isolation and thus it will be able to easily adopt the shared space concept. Den type offices are designed to cater to team-oriented operations and thus have more flexible office layouts.

Since the culture of an organization will help its employees to understand the basic assumptions, values and behaviours expected from them, it is important to understand the factors that influence employee perceptions of the organizational culture (Ofori & Sokro, 2010). A shared workspace rented out to outside parties can influence the employees' perception of the culture. This fact was emphasised during case study interviews although not much emphasised in the literature. According to case study findings, an organizational culture with flexible work practices will be more conductive to adopting the concept of shared workplace. In a culture that has rules and regulations, employees are judged by what they achieve rather than how they carry out their tasks. The experts, however, strongly disapproved this fact saying that the culture of an organization influences only the time the workers come to work and where they work, eat, and relax. A culture with no strict rules and regulations will contribute to making business activities successful. Furthermore, to be able to have a shared workspace in an office, there has to be a flexible environment.

The higher the contribution of the support structure of a building make to any of its activities, the higher will be the performance of the building occupants in that activity. Thus, for a shared workspace to properly function, there has to be backup power systems and associated support structures that come into operation whenever there is a breakdown of the regular power supply or systems as otherwise the customers will become dissatisfied making their retention difficult. If a shared workspace that fails to give backup power or other supporting services with proper and regular maintenance will lose its reputation and customers.

Accessibility of the buildings, as revealed by case study findings, is another important factor when looking out for shared space. A separate access will always be preferred by parties rather than a common access or an access through the office space of the organization itself. A separate access can, however, disturb the day to day operations of the organization while posing a threat to the organization.

The acceptability of the concept of shared workspace can vary from business to business. Irrespective of the type of their buildings, not all organizations with unutilized space will want to adopt the concept as at times they will prefer to be left with unutilized spaces rather than renting out those spaces. Both practitioners and researchers in their individual capacities were interested in co-working using shared workspace. In the literature, the co-working concept has been highlighted as a separate business opportunity and not as a merger with the existing office operations. This study was on identifying how organizations can sustainably utilize their unutilized spaces.

5. CONCLUSIONS AND RECOMMENDATIONS

The study has been able to attain its research aim and associated objectives through its findings and outcomes. At a time when shared workspace is still novel to Sri Lanka, this study will draw the attention of the readers to the importance of using the office buildings in the country sustainably. Through the literature review done on the shared workspace concept nine reasons for adopting shared workspaces in office buildings could be identified. They indicate why a modern person will prefer shared space to ordinary office space. The study also identified ten spaces within an organization which included board rooms, meeting rooms and workstations as areas that can be shared. To be able to share its unutilized space, an office building needs to possess certain characteristics. These characteristics together will provide a platform to building owners to ascertain the adaptability of their buildings for space sharing. For a developing country like Sri Lanka, this concept will be useful to both building owners and their clients who are interested in making use of their idling space more productively.

It is recommended that action be taken to more systematically implement the shared workspace concept in Sri Lanka. All stakeholders need to be made aware of the advantages of this concept and how it can be implemented. In Sri Lanka, there is currently a growing tendency towards setting up start-ups as single entities by individuals and small groups. The government can financially assist these start-ups by reducing the taxes charged for shared workspaces so that there is encouragement to use shared spaces. Building designers can create flexible spaces suitable for sharing at a future date and thereby contribute to the betterment of Sri Lanka.

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ADDRESSING RISKS IN GREEN RESIDENTIAL BUILDING CONSTRUCTION PROJECTS: THE CASE OF SINGAPORE

Bon-Gang Hwang, Ming Shan* and Helena Phua

Department of Building, National University of Singapore, 4 Architecture Drive, Singapore

ABSTRACT

Over the past decade, an increasing number of green residential buildings have been developed worldwide owing to active promotion from the authorities and the increasing interest from customers. However, in the same way as traditional residential buildings, the construction of green residential buildings has been facing various risks. The aims of this study are to identify and assess the diverse risks in green residential building construction projects, compare their risk criticalities with those in traditional counterparts, and propose helpful risk mitigation measures. To achieve these goals, a comprehensive literature review was conducted first, and then a questionnaire was administered to 30 construction companies in Singapore. The analysis results showed that "complex procedures to obtain approvals", "overlooked high initial cost", "unclear requirements of owners", "employment constraint", and "lack of availability of green materials and equipment" were the top five critical risks in green residential building construction projects. It also reported that green residential building projects were facing risks at a more critical level than those traditional residential building projects. Furthermore, this study proposed fourteen risk mitigation measures that can effectively tackle the risks in green residential building construction projects. This study contributes to the body of knowledge by identifying and evaluating the critical risks and the responding mitigation measures in green residential building construction projects. The findings from this study can also provide practitioners with an in-depth understanding of risk management in green residential building construction projects, and thereby benefiting the industry.

Keywords: *Critical Risks; Green Residential Building Construction Projects; Mitigation Measures.*

1. INTRODUCTION

Today, it is widely recognized that human activities are accountable for various global crises such as climate change, resource depletion, and environmental degradation, and one representative of these activities is construction (Zhao et al., 2016). According to the United Nations Environment Program (UNEP, 2001), the construction industry has become a big energy consumer who uses 40–50 percent of global energy and 40 percent of global raw materials; and also a principal waste contributor who releases 40 percent of global greenhouse gas emissions and produces 40 percent of solid waste worldwide. These anxiety-provoking numbers exert considerable pressure on authorities worldwide who therefore decide to adopt and promote the concept of green building in the global construction industry (Qin et al., 2016).

In a typical densely populated city-state like Singapore, a large number of residential buildings must be built to satisfy people's need for housing (Agarwal et al., 2016). Based on the statistics released by Department of Statistics (2017), residential buildings occupy 37 percent of building work in Singapore and are the largest ingredient of the local construction market. Thus, naturally, the residential buildings came to be the primary target for the authorities of Singapore to promote green buildings. Over the recent years, considerable efforts have been made by the local authorities. For instance, in 2007, the Housing and Development Board (HDB) began developing environmentally-friendly public housing blocks (e.g. Punggol Eco-Town) in Singapore (HDB, 2016b). In 2012, HDB started retrofitting the existing, old and traditional residential buildings by installing green and sustainable features (HDB, 2016a). Furthermore, the Building and Construction Authority

*Corresponding Author: E-mail – bdgsm@nus.edu.sg

(BCA) of Singapore launched a series of green regulations like BCA Green Mark for New Residential Buildings and BCA Green Mark for Existing Residential Buildings since 2010, in order to regulate and foster the development of green building in the residential building sector of Singapore (BCA, 2010; BCA, 2011).

Inevitably, construction projects face diverse risks (Hwang et al., 2015a), and the green residential building construction projects are no exception. Particularly, due to extensive use of complicated construction technologies and innovative materials, the risks embedded in green residential building construction projects might be different from those involved with traditional residential building construction projects (Zhao et al., 2016). Thus, this paper proposed a research hypothesis that the risk criticalities between green and traditional residential building construction projects were different. To test this hypothesis, this study therefore identified risks in green residential building construction projects, assessed and compared their risk criticalities between the green and traditional contexts. Moreover, this paper also provided a set of useful risk mitigation measures to tackle the risks in green residential building construction projects.

Although there are already several studies addressing risks in green building construction projects (Dewlaney et al., 2011; Yang & Zou, 2014, Qin et al., 2016, Yang et al., 2016), very few investigated the risks in green residential building construction projects. Therefore, this study can contribute to the body of knowledge of green buildings. Additionally, findings from this study can also enhance practitioners' awareness of risk management in green residential building construction projects, and thus contribute to the industry.

2. BACKGROUND

2.1. GREEN BUILDINGS AND GREEN RESIDENTIAL BUILDINGS IN SINGAPORE

Singapore is a city-state with limited natural resources and land area (Hwang et al., 2015a; Zhao et al., 2016), making sustainability a necessity rather than an option to the country. Over the past three decades, Singapore has been struggling to integrate sustainability in its various industries, and the construction industry is one of its primary emphases. In 2005, Singapore government kick-started the green building campaign by introducing BCA Green Mark scheme. Since then, Singapore has advanced three rounds of Green Building Masterplans (i.e., Masterplans of 2006, 2009, and 2014) successively to promote the green building movement in the country (BCA, 2014). In the meantime, Singapore government also launched a series of incentive schemes (e.g., Green Mark Incentive Scheme for New Buildings in 2006 and Green Mark Incentive Scheme for Existing Buildings in 2009) to encourage building owners, developers, and contractors to develop and construct more green buildings (BCA, 2015c; BCA, 2015d). Stimulated by this comprehensive suite of policies and initiatives, the green built environment in Singapore achieved rapid development, and the numbers of green buildings increased greatly, from 17 in 2005 to over 2,100 in 2014 (BCA, 2014).

Singapore has devoted considerable efforts to greening residential buildings in the past few years. In 2010, BCA launched BCA Green Mark for New Residential Buildings to encourage developers, building owners, and architecture firms to develop green and sustainable buildings that can achieve more energy and resource savings (BCA, 2010). In 2011, BCA launched BCA Green Mark for Existing Residential Buildings further to help building owners and facility operators retrofit their existing buildings with green and sustainable features (BCA, 2011). Meanwhile, Singapore has also started to develop new sustainable residential blocks. In 2007, HDB, National Environment Agency, Public Utilities Board, and the Economic Development Board jointly developed the Treelodge@Punggol (Punggol, Singapore), the first eco-precinct in Singapore (HDB, 2016b). Additionally, in 2012, HDB launched HDB Green Print scheme retrofitting the existing, traditional, and old residential buildings (HDB, 2016a). This scheme has been piloted successfully in Yuhua Estate, Singapore between 2012 and 2015, which has benefited the 3,200 households living in that estate (Kelleher, 2015).

2.2. RISKS IN GREEN BUILDING CONSTRUCTION PROJECTS

Although research of the risks in green residential building construction projects is limited, research in generic green construction projects keeps increasing recently (Hwang *et al*., 2015a). Considering risks in generic green construction projects are also applicable to green residential building construction projects, a comprehensive review of risks in generic green construction projects was therefore conducted aiming to help create a comprehensive list of risks for green residential building construction projects.

Existing literature has addressed a wide range of risks in generic green construction projects. Ranaweera and Crawford (2010) emphasized that green building construction projects faced a higher financial risk compared to their traditional counterparts because the adoption of the environmental strategies typically required a higher investment which would cause cost overruns to projects. Dewlaney *et al.* (2011) and Fortunato Iii *et al*. (2011) found that workers on LEED certified projects were exposed to work at height, near unstable soils, with electrical current, and near heavy vehicles and equipment for a longer duration than those working on traditional projects. Tollin (2011) stated that green building construction projects confronted a significant risk of failure due to defects and omissions by design professionals, contractors, and subcontractors. Also, Tollin (2011) emphasized that owners of green building construction projects would face risks of being sued by occupants or tenants, losing tax credit, and losing beneficial financing or loan, if their projects fail to achieve the expected level of green certification. Zou and Couani (2012) summarized 40 risks associated with green building development in Australia and conducted a survey. Their survey results suggested that the top five important risks were a higher investment, lack of commitment in the supply chain, lack of shared information on green building, additional costs in skills development, and lack of expertise regarding green building. Using the approach of Social Network Analysis (SNA), Yang and Zou (2014) and Yang *et al.* (2016) developed stakeholder-associated risk models to examine the risks in green building construction projects. They found that diverse stakeholders recognized ethical/reputational risks more widely and that technological risks were not important as perceived. Hwang *et al.* (2015a) identified and evaluated 20 risk factors in green retrofit projects, and they discussed the top eight risk factors in details, which were risks associated with post-retrofit tenants' cooperation, regulations, market demand, project finance, pre-retrofit tenants' cooperation, concerns from stakeholders, material supply and availability, and construction quality. Through a questionnaire survey, Qin *et al.* (2016) assessed risks in Chinese green building construction projects and found the top five critical risks were complicated approval procedures due to government bureaucracy, poor maintenance in green buildings, lack of design experience on green buildings, lack of experienced property management for green buildings, and inaccurate green goal established by the owner/developer. The in-depth review above provided a solid basis for the identification of risks in green residential building construction projects.

2.3. Risk Mitigation Measures in Green Building Construction Projects

Accompanying the identification of risks are recommendations for risk mitigation measures. Ranaweera and Crawford (2010) proposed a decision-making tool to assess the potential of incorporating environmental strategies into to the development of building projects, which may alleviate financial risks caused by sustainable design. Tollin (2011) recommended that insurance products could be used to minimize financial risks in green building construction projects. To mitigate safety risks of LEED certified projects, Fortunato Iii *et al*. (2011) suggested encouraging the use of prefabrication, because prefabrication allowed workers to assemble green-tech equipment indoors, which could spare workers from ascending and descending ladders and lifting components overhead during installation on site and thus minimize the potential safety hazard. Zou and Couani (2012) stated that risks in green construction projects could be alleviated by strengthening research and development (R&D), providing professionals with proper training and education, and ensuring coordination and information sharing among various contracting parties. After using their SNA-based risk management model to analyse risks in one green education building construction project in Australia, Yang and Zou (2014) found that improving communications and interactions among various contracting parties could effectively mitigate risks in green construction projects. In addition, Hwang *et al.* (2015a) recommended a set of measures to tackle risks in green retrofitting projects, and they highly recommended the following measures, hiring consultants with sufficient experience in managing green building construction projects to mitigate regulatory risk, increasing public awareness of the benefits of green buildings to minimize market risk, using the delivery method of Design and Build to settle communication issues among various contracting parties, and using equipment and materials that have been sufficiently tested to ensure project quality.

3. Research Methods and Data Presentation

3.1. Data Collection and Presentation

This study administered a questionnaire to assess risks and the relevant mitigation measures in green residential building projects in Singapore. Based on the literature review, 42 risks and 14 risk mitigation measures were identified and then used to form a questionnaire. Two industry experts who had at least five years of experiences in both traditional and green building constructions in Singapore were involved reviewing the questionnaire to check statement comprehensiveness, readability, and accuracy. The finalized questionnaire consisted of three sections, which were to; (1) profile respondents and their affiliated companies, (2) assess the likelihood and impact of each risk in both green and traditional residential building construction projects, and (3) evaluate the effectiveness of the risk mitigation measures. Furthermore, open-ended questions were also positioned in the questionnaire, allowing for any supplement of new risks and mitigation measures.

The population of the questionnaire was the BCA registered construction companies that have experience in both green and traditional building constructions in Singapore. After a careful check of the work scope and experiences, a total of 100 qualified companies were randomly identified from the BCA directory for data collection. Questionnaires were sent to these companies via emails. Phone calls and email reminders were sent every week if the dispatched questionnaires were not returned. Finally, 30 valid responses were received, representing a response rate of 30 percent. This response rate was aligned with the norm of 20 to 30 percent in most questionnaire surveys in construction engineering and management research (Akintoye, 2000). Table 1 profiles the backgrounds of the companies and respondents. It could be noted that the respondent companies comprised various project stakeholders such as consultants, developers, contractors, and architecture firms. Moreover, 53 percent of respondents had at least five years' experience in traditional residential building construction projects, and 63 percent of respondents had at least three years' experience in green residential building construction projects, suggesting that the respondent panel had requisite experience to address the research questions of the questionnaire.

Table 1: Backgrounds of the Respondents and their Companies

Profile	Frequency	Percentage
Company (total = 30)		
Type		
Consultancy	12	40.00
Developer	1	3.33
Contractor	10	33.33
Architecture firm	7	23.33
Respondent (total = 30)		
Job title		
Project Manager	1	3.33
Architect	6	20.00
Engineer	3	10.00
Quantity Surveyor	15	50.00
Consultant	5	16.67
Years of experience in traditional residential building projects		
Less than one year	2	6.67
1 to 2 years	4	13.33
3 to 4 years	8	26.67
5 to 10 years	11	36.67
More than ten years	5	16.67
Years of experience in green residential building projects		
Less than one year	3	10.00
1 to 2 years	8	26.67
3 to 4 years	12	40.00
5 to 10 years	7	23.33
More than ten years	0	0.00

4. DATA ANALYSIS AND DISCUSSIONS

4.1. LIKELIHOOD, IMPACT AND CRITICALITY OF RISKS IN GREEN RESIDENTIAL BUILDING CONSTRUCTION PROJECTS

This paper calculated the mean values of the likelihood of occurrence (LO) and magnitude of impact (MI) of each risk in green residential building construction projects and presented them in Table 2. Regarding the LO values, 28 out of 42 risks were assessed above 3, suggesting 67 percent of risks were fairly likely to occur in green residential building construction projects. As for the MI values, 37 out of 42 risks received MI values above 3, suggesting 88 percent of risks had fairly significant impacts on green residential building construction projects. Furthermore, this paper calculated the risk criticality (RC) of each risk by multiplying its LO and MI value, following the recommendation of Deng et al. (2014). As the assessments of LO and MI were both carried out with a five-point rating system, the RC was thus on a full scale of 25. Accordingly, this paper established a benchmark of 9 to identify the critical risks, namely the product of the median values of LO and MI rating scales. According to the results in Table 2, 35 out of 42 risks scored above 9, suggesting 83 percent of risks were critical risks to green residential building construction projects. Particularly, the top five risks in RC, namely "R6 - Complex procedures to obtain approvals", "R26 - Overlooked high initial cost", "R15 - Unclear requirements of owners", "R8 - Employment constraint", and "R28 - Lack of availability of green materials and equipment," scored above 14, indicating they were extremely critical to green residential building construction projects. Due to the space limit, only these five risks were discussed in details in this paper. As the respondents of the questionnaire have different backgrounds, Kruskal-Wallis test was conducted to check if different backgrounds of the respondents could affect their assessments. The test results reported no significant differences among the respondents, indicating the respondents held unanimous views.

Table 2: Assessments of Risks in Green and Traditional Residential Building Construction Projects

Code	Description	Green						Traditional		Wilcoxon signed-rank test	
		RC	Rank	LO	Rank	MI	Rank	RC	Rank	Difference	p-value
R6	Complex procedures to obtain approvals	17.27	1	4.20	1	4.00	1	9.73	2	7.54	0.000*
R26	Overlooked high initial cost	16.67	2	4.13	2	3.97	2	8.60	9	8.07	0.000*
R15	Unclear requirements of owners	15.07	3	3.90	3	3.73	6	8.40	13	6.67	0.000*
R8	Employment constraint	14.47	4	3.83	4	3.73	6	10.00	1	4.47	0.000*
R28	Lack of availability of green materials and equipment	14.17	5	3.57	6	3.80	4	7.40	23	6.77	0.000*
R22	Lack of qualified professionals with proper design expertise	13.53	6	3.53	8	3.70	8	5.50	32	8.03	0.000*
R24	Unfamiliarity of job requirement	13.50	7	3.37	14	3.87	3	7.10	25	6.4	0.000*
R27	Technical Issues	13.00	8	3.70	5	3.40	14	7.53	22	5.47	0.000*
R19	Unclear design details and specifications	12.87	9	3.53	8	3.43	12	7.63	21	5.24	0.000*
R40	Unfamiliarity with new technology rates	12.77	10	3.57	6	3.40	14	8.00	16	4.77	0.000*
R41	Fluctuations in labor/material rates	12.63	11	3.40	12	3.50	11	9.57	3	3.06	0.000*
R33	Unskilled workers	12.23	12	3.47	11	3.30	22	9.27	5	2.96	0.004*
R42	High Target for Green Mark Rating	12.00	13	3.40	12	3.40	14	6.20	28	5.8	0.000*
R36	Inefficient Communication	11.83	14	3.20	20	3.53	10	9.30	4	2.53	0.021*
R29	Lack of technical expertise	11.67	15	3.33	16	3.37	20	6.43	27	5.24	0.000*
R39	Inaccurate estimation	11.57	16	3.37	14	3.30	22	9.13	6	2.44	0.001*

Code	Description	Green						Traditional		Wilcoxon signed-rank test	
		RC	Rank	LO	Rank	MI	Rank	RC	Rank	Difference	p-value
R20	Being fined for failing to achieve Green Mark standards	11.53	17	3.13	25	3.23	26	4.70	35	6.83	0.000*
R14	Shortage of funds	11.50	18	2.97	29	3.77	5	8.33	14	3.17	0.000*
R25	Exposed to lawsuit for failing to achieve GM standards	11.43	19	3.03	28	3.60	9	6.03	29	5.4	0.000*
R34	Poor Design	11.37	20	3.27	18	3.43	12	8.27	15	3.1	0.002*
R31	Lack of experience	11.33	21	3.23	19	3.20	30	6.03	29	5.3	0.000*
R7	Safety and health	11.30	22	3.20	20	3.40	14	9.27	5	2.03	0.030*
R30	Unfamiliarity with green materials and construction technologies	11.23	23	3.53	8	3.00	37	5.87	31	5.36	0.000*
R38	Unfamiliarity with construction process	11.17	24	3.30	17	3.23	26	8.40	13	2.77	0.013*
R32	Setting expectations too high	11.00	25	3.20	20	3.17	32	8.50	12	2.5	0.011*
R4	Fluctuation in exchange rates	10.97	26	3.10	27	3.23	26	7.70	19	3.27	0.034*
R9	Pollution restrictions	10.63	27	3.17	23	3.20	30	8.53	11	2.1	0.051
R12	Unclear contract conditions for dispute resolution	10.60	28	3.13	25	3.27	25	8.57	10	2.03	0.000*
R11	Unclear contract conditions for claims and litigations	10.27	29	2.93	30	3.40	14	7.93	17	2.34	0.003*
R35	Poor Workmanship	10.03	30	3.17	23	3.10	36	9.00	8	1.03	0.168
R21	Poor communication among projects stakeholders	9.87	31	2.90	32	3.33	21	9.10	7	0.77	0.325
R37	Lack of management staff	9.83	32	2.80	34	3.17	32	7.53	22	2.3	0.011*
R3	Inflation	9.80	33	2.93	30	3.13	35	7.87	18	1.93	0.003*
R23	Claims of overstated or unverifiable benefits	9.73	34	2.87	33	3.40	14	6.60	26	3.13	0.001*
R17	Loose control over subcontractors	9.13	35	2.77	35	2.97	38	7.67	20	1.46	0.002*
R18	Warranties to homeowners of green building	8.93	36	2.77	35	2.90	39	5.37	34	3.56	0.000*
R10	Import/ export restrictions	8.93	36	2.60	38	3.30	22	6.60	26	2.33	0.003*
R16	Inappropriate interventions of clients	8.63	38	2.77	35	2.87	40	6.20	28	2.43	0.015*
R13	Unclear allocation of roles and responsibilities	7.60	39	2.40	39	2.77	41	7.27	24	0.33	0.916
R2	Energy saving uncertainty	7.47	40	2.23	40	3.17	32	6.00	30	1.47	0.137
R1	Green building policies change	6.10	41	1.87	41	3.23	26	5.47	33	0.63	0.059
R5	High crime rate	3.37	42	1.50	42	1.90	42	3.03	36	0.34	0.776

Note: *The Wilcoxon signed-rank test is significant at the 0.05 significance level.

"R6-Complex procedures to obtain approvals" was the most critical risk due to receiving the highest RC value of 17.27. This was because green residential building projects always involve some particular green features (e.g., solar photovoltaic system, pneumatic waste conveyance system, and rain harvesting system), which would result in lengthier planning approval and permit procedures (Zhao *et al*., 2016). This risk has also been assessed as the most critical risk in Chinese green building projects by Qin et al. (2016). "R26-Overlooked high initial cost" was ranked second with a RC value of 16.67, attributed to its second highest LO and MI values. Compared to traditional residential building construction projects, green residential building construction projects involve higher initial costs owing to the enormous up-front costs caused by the use of green technologies and materials and additional consultancy services (Zou & Couani, 2012). This result echoed findings from Robichaud and Anantatmula (2010) who also stressed that high initial cost was a significant barrier to the promotion of green buildings. "R15-Unclear requirements of owners" received the third position with a RC value of 15.07. Owners who have insufficient knowledge and experiences of green residential buildings might not be able to give clear and specific requirements to designers and contractors. For instance, the unclear requirements from the clients might result in designers' misinterpretation or misunderstanding of the clients' real purposes, which would lead to numerous design changes and considerable reworks eventually. This result also echoed Hwang *et al*. (2015b) who recognized unclear requirements of owners as a critical issue affecting the performances of green building construction projects in Singapore.

"R8-Employment constraint" was ranked fourth with a RC value of 14.47. Being a country with limited human resources, Singapore is always leveraging on foreign workforces to ensure its economic growth (Robichaud & Anantatmula, 2010). Nonetheless, the Singapore government has established some control mechanisms to regulate the number of foreign workers to avoid the local Singaporeans being priced out of the job market. Unfortunately, foreign workforces with green residential building construction experiences are categorized by the Ministry of Manpower Singapore as the unskilled or semi-skilled workforce, which are under the strict control on issuing work permit (Low, 2002). Thus, the constructions of local green residential building projects might face a lack of sufficient workforce because of this employment constraint. "R28-Lack of availability of green materials and equipment" was assessed as the fifth most critical risk with a RC value of 14.17. In Singapore, the majority of construction equipment, materials and even plants designated for green residential building construction projects need to be imported from overseas, which normally requires a long period to be delivered on site (Hwang *et al.,* 2015a; Hwang *et al.*, 2015b; Zhao *et al.*, 2016). Therefore, any hang-up relating to the delivery of imported equipment and materials, especially for those referring to the critical activities in project scheduling, would significantly affect the successful delivery of the project. Such a result was in line with the findings from Zhao *et al*. (2016) who also emphasized that availability of materials and equipment was a significant risk requiring additional attention in green building construction projects.

4.2. *RISK CRITICALITIES: GREEN VERSUS TRADITIONAL RESIDENTIAL BUILDING CONSTRUCTION PROJECTS*

To explore the possible differences in RC values between green and traditional residential building construction projects, this paper conducted the Wilcoxon signed-rank test. This method is a non-parametric statistical test comparing two sets of scores that come from the same participants, without requiring the data must be normally distributed (Hwang & Leong, 2013). In this study, test results showed that the p-values of 35 risks were less than 0.05, suggesting there were significant differences in RC values of the most risks between green and traditional residential building construction projects. These results meant that the hypothesis of this study, namely, risk criticalities between green and traditional residential building projects were different, was supported. Furthermore, the RC values of these 35 risks in green residential building construction projects were statistically greater than those in traditional residential building construction projects, implying that green residential building construction projects are facing risks at a more critical level.

"R26-Overlooked high initial cost" received the greatest difference between the two types of projects. The RC value of this risk in green residential building construction projects (i.e. 16.67) is almost two times of that in traditional residential building construction projects (i.e. 8.60). This was probably because, compared to traditional residential building construction projects, green residential building construction projects requires considerable upfront expenditures on green technologies, materials, and equipment (Shiers *et al.,* 2006). This result was also supported by Zou and Couani (2012) who claimed that the perceived higher upfront costs were the largest obstacle to green building development. "R22-Lack of qualified professionals with proper design expertise" received the second greatest difference in RCs. This risk received a high rank in green residential building construction projects (i.e. 6), but a low rank in traditional residential building construction projects (i.e. 32), implying that it was more critical to green residential building construction projects. This might be because, compared to those traditional ones, green residential building construction projects require skilled design professionals to handle specialized green and sustainable designs; while the reality in Singapore is that competent and experienced local green design professionals are extremely deficient (Hwang *et al.,* 2015a).

"R6-Complex procedures to obtain approvals" obtained the third greatest difference in RCs. Although this risk received high ranks in both groups, its RC values were significantly different between two types of projects: 17.27 with green versus 9.73 with traditional. This result could be explained by the fact that green residential building construction projects involve more innovative technologies, materials, and equipment compared to traditional construction projects. Thus, it has to undergo a stricter approval process imposed by the construction authority (Zhao *et al.*, 2016), which inevitably makes the processing time longer than that for traditional residential building construction projects. "R20-Being fined for failing to achieve Green Mark standards" received the fourth greatest difference in the RC assessment, and in particular, its RC value in green residential building construction projects (i.e., 11.53) was much higher than that in traditional ones (i.e., 4.70). In fact, this is a unique risk of green residential building construction projects. In Singapore, the Building Act has required that any new buildings and existing ones that undergo major retrofitting must achieve the minimum Green Mark Certified Level; otherwise, a certain amount of fines will be imposed (Ismail, 2013). "R28-Lack of availability of green materials and equipment" was ranked fifth in RC difference. This risk received a low rank (i.e., 23rd) in traditional residential building construction projects, but a high rank (i.e., 5th) in green ones. This was probably because the green construction industry in Singapore was a young industry and thus the supply of green materials and equipment might be still limited; in contrast, the traditional construction industry had already been fully mature, and thus the common materials and equipment were more widely available comparatively (Hwang *et al.*, 2015a). This result was also in line with Hwang and Leong (2013) who argued that material supply and availability was more critical in green building construction projects compared to traditional building construction projects.

4.3. PROPOSED MITIGATION MEASURES

This study also asked respondents to evaluate the effectiveness of the 14 risk mitigation measures (RMMs) generated from literature. As Table 3 shows, all 14 risk mitigation measures received mean values higher than 3, indicating all of them were effective in tackling risks in green residential construction building projects in Singapore. Those mitigation measures that received evaluations above four are discussed as follows.

Table 3: Assessments of Risk Mitigation Measures for Green Residential Building Construction Projects in Singapore

Code	Risk mitigation measure	Mean	Rank
RMM10	Improving communication and coordination among contracting parties	4.57	1
RMM12	Understanding owner's goal of the Green Mark Standard	4.27	2
RMM13	Using past successful green residential projects as references	4.20	3
RMM5	Developing training programs to upgrade workers' skills and knowledge on new technologies and materials	4.20	3
RMM1	Allowing for contingency funds	4.13	5
RMM6	Devoting adequate resources to planning and research	3.90	6
RMM9	Front end planning	3.83	7
RMM2	Communicating about targeted green mark rating and ways to achieve that with a clear roles and responsibilities chart	3.77	8
RMM3	Contract language to be precise and give provision to limit each parties' liabilities	3.67	9
RMM4	Constant design evaluation and verifications	3.53	10
RMM11	Implementing passive design instead of complicated active building design	3.50	11
RMM7	Enhanced communication tool for better collaboration (e.g., BIM software)	3.4	12
RMM14	Working with experienced insurance agent to receive better coverage protection	3.30	13
RMM8	Effective change management	3.10	14

"RMM10-Improving communication and coordination among contracting parties" was assessed as the most effective measure with the highest evaluation of 4.57. To ensure the success of a green residential building construction project, a higher level of communication among the contracting parties is demanded. This is because green residential building construction projects normally require a multidisciplinary team with a more comprehensive professional composition to handle those complicated and innovative technologies, equipment, and materials adopted in such projects (Yang & Zou, 2014). Any information isolation among team members will probably raise various issues such as rework, delay, and cost overrun. This result was in line with Hwang and Tan (2012) who also stated that project team's communication was an effective solution to overcome obstacles in green building construction projects. "RMM12-Understanding owner's goal of the Green Mark Standard" received the second highest value (i.e., 4.27) in the effectiveness evaluation. In Singapore, each new residential building is mandatory to achieve some Green Mark Standard (BCA, 2015b). Thus, it is crucial for the designer, consultant, and contractor to understand owner's goal of Green Mark Standard for the building before they start working on the project. Zou and Couani (2012) obtained the similar conclusion that communicating green building objectives clearly to all the project team members is vital to secure the success of a green building construction project.

"RMM13-Using past successful green residential projects as references" was assessed as the third most effective measure with an evaluation of 4.20. Referring to successful experiences of past projects is an effective measure to mitigate risks in new construction projects. To date, Singapore has accumulated some valuable experiences in developing green residential buildings since it introduced the Green Mark for Residential Buildings in 2011. These experiences can render considerable help to new green residential building construction projects in mitigating risks and achieving a better project performance. This result was comparable to Zou and Couani (2012) who stated that experience accumulation was an important strategy to reduce risks in green building supply chain. "RMM5-Developing training programs to upgrade workers' skill and knowledge of new technologies and materials" was also assessed as the third most effective measure with a value of 4.20. During constructions of green building projects, one major issue is that frontline workers might be unfamiliar with innovative technologies and materials adopted in such projects (Hwang & Tan, 2012). Thus, it is crucial to develop a series of training programs for those frontline workers and make sure that they are well trained and informed of the green technologies they are about to use. Currently, the BCA has rolled out some green courses (e.g., Green Mark Professional course and Green Mark Facilities Professional course) to help the local industry advance their knowledge and capability in undertaking green building construction projects, which are very popular with local construction community (BCA, 2015a). "RMM1-Allowing for contingency funds" received the fourth highest value (i.e. 4.13) in the effectiveness evaluation. This risk mitigation measure was highlighted as the complex nature of green residential building construction projects makes the exact budget of the project impossible to forecast accurately. Also, innovative and complicated green technologies adopted in green residential building construction projects might require additional tests and inspections (Häkkinen & Belloni, 2011), which would also lead to additional cost beyond the original project estimation. Therefore, it is extremely necessary to set aside some contingency funds to entail some unexpected but possible risks. In fact, contingency funds have also been used widely by traditional construction projects to manage their risks (Ford, 2002).

5. CONCLUSIONS AND RECOMMENDATIONS

Green residential buildings have achieved a rapid development over recent years due to its positive efficacy of saving energy and resources consumptions. However, risks embedded in the construction of green residential buildings are not adequately addressed. As a result, this paper conducted an exploratory research to investigate risks and the relevant mitigation measures in green residential building construction projects.

A total of 42 risks and 14 mitigation measures were identified from a comprehensive literature review first and then included in a questionnaire administered with 30 Singapore-based construction companies. The results of the questionnaire showed that the top five critical risks in green residential building projects were "complex procedures to obtain approvals", "overlooked high initial cost", "unclear requirements of owners", "employment constraint", and "lack of availability of green materials and equipment". It also revealed that 35 out of 42 identified risks obtained significantly higher assessments in green residential building construction projects than in traditional residential building construction projects, suggesting that they are more critical in the former. Moreover, the results of the questionnaire presented the top five most effective risk mitigation measures in green residential building construction projects: "improving communication and coordination among contracting parties", "understanding owner's goal of the Green Mark Standard", "using past successful green residential projects as references", "developing training programs to upgrade workers' skill and knowledge of new technologies and materials", and "allowing for contingency funds".

In spite of the detailed investigation of critical risks and the relevant risk mitigation measures in green residential building construction projects, some limitations are still present in this study. First, the sample size of the survey in this study is relatively small. Thus, cautions should be given when the analysis results are interpreted and generalized. Second, the risk criticality index calculated in this study is subjective to a certain extent and may be biased subject to individual experience and risk preference. Third, findings from this study apply to Singapore exclusively, which may vary in other different countries. Despite these limitations, this study is still valuable. This is the first systematic investigation of the various risks and the relevant mitigation measures in green residential building construction projects. Thus, this study contributes to the current body of knowledge. Furthermore, this study is also useful to the practice. As the findings from this study are derived from the first-hand experiences gathered from the industry practitioners of Singapore, which is a widely recognized pioneer and a global leader in the area of green building construction. This study is also useful to other countries that are about to promote green residential buildings. For instance, relying on the findings from this study, industry practitioners in other countries can gain a deeper understanding of risks in green residential building construction projects, develop a customized risk check list for their own green residential building construction projects, and also may come up with some more effective strategies to address those risks.

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ANALYSING COMPLEXITIES AND UNCERTAINTIES IN INDIAN MEGAPROJECTS

Jay Mevada and Ganesh Devkar*

Faculty of Technology, CEPT University, India

ABSTRACT

In India, the demand of infrastructure has been burgeoning rapidly owing to economic development and rapid pace of urbanization. Increasingly, the infrastructure planning and implementation strategy indicates the policy makers are leaning towards fulfilling this demand with megaprojects, having large scope and size, in terms of cost and resource requirements. The performance of these megaprojects has been dismissal with substantial time and cost overruns. The uncertainties and complexities associated with megaprojects is recognized as a major hurdle in effective implementation of megaprojects. There has been diversity of mechanisms adopted for managing complexities in Indian megaprojects. This paper analyses the case studies of Indian megaprojects to determine the types of mechanisms followed managing complexities as well as their effectiveness. Based on this analysis, the areas of improvement in existing mechanisms have been suggested, which would be help to the policy makers and ensure smoother implementation of megaprojects.

Keywords: *Complexity; India; Megaprojects; Uncertainty.*

1. INTRODUCTION

Infrastructure development continues to be one of the central themes of policy making in any country. Over the years, the aspirations of politicians, administrators and citizens alike have increased in terms of scope as well as scale of infrastructure projects. This has resulted in the emergence of projects involving large scale investments and resources. The global megaproject spending was pegged at US$ 6 to US$ 9 trillion annually, or 8% of the total global gross domestic product in 2014 (Flyvbjerg, 2014). There are different connotations for these types of projects such as large engineering projects, megaprojects and major projects. Leaving aside the differences in the terminologies, it may be said that the cost of a project is an important parameter that can categorise it as a megaproject or not. According to the US Department of Transportation, megaproject is a project with at least USD 1 billion budget while European (EU) and International Project Management Association stipulate a cost threshold of 100 million Euros (Flyvbjerg *et al.*, 2003).

The process of conversion of megaproject aspirations into reality is fraught with many challenges. Flyvbjerg (2014) has been researching and tracking the performance of megaprojects across the world; his analyses show that nine of ten megaprojects have cost overruns of up to 50 percent and consequential time overruns. Apart from the typical performance parameters - time and cost, megaprojects have piecemeal track record in the areas of sustainability, stakeholder participation, transparency, environmental compliance and accountability. The complexities and uncertainties associated with megaprojects is considered an important reason for the various challenges faced in the implementation of megaprojects. Therefore, the management of complexity and uncertainty is critical for realization of the benefits of megaprojects.

The Indian scenario on megaprojects is akin to international trends. The Ministry of Statics and Programme Implementation (MoSPI) of the Government of India uses the term "megaprojects" for those that cost US$ 156 million and above. In India the number of megaprojects has increased by 40 percent from 2012 to 2016. Forty five percent of the projects, on the average, are delayed. The time overrun ranges from 2 months to 24 months

*Corresponding Author: E-mail – ganesh.devkar@cept.ac.in

(Mevada & Devkar, 2017). Although, the cost implications owing to these time overruns are not monitored by MoSPI, they are substantial. In this context, this paper aims to analyse the mechanisms adopted for managing complexities and uncertainties in Indian megaprojects. The outcome of this analysis will be helpful to policy makers for improving the existing mechanisms.

This paper is structured into six sections. The following second section provides an overview of literature on complexity and uncertainty management in megaprojects. The case study research method adopted in this reported work is described in the third section. The background of Indian megaprojects and a case study analysis is presented in sections four and five respectively. The sixth section provides the summary and discusses the future scope of research.

2. MEGAPROJECTS AND COMPLEXITY: AN OVERVIEW

The management of complexities and uncertainties for effective megaproject implementation has been widely discussed in literature. Apart from papers specifically focusing on complexity from the viewpoint of megaprojects, there is a growing body of knowledge in the area of implementation of complex projects or complex project management. He *et al.* (2015) reviewed the key papers of both types and derived a six category complexity framework that included technological, organizational, goal, environmental, cultural and information complexities. Each complexity was conceptualized as a factor and the factors were measured with sub factors associated with each complexity. The number of factors associated with each complexity were as follows: technological (4), organizational (4), goal (4), environmental (7), cultural (4) and information (5). This framework not only maps the complexity categories but also maps measures / concepts for each complexity mentioned in different papers. Therefore, this complexity framework has been used as a reference in this study.

Giezen (2013) states that “complexity is often considered to be a problem, it is uncertainty built into that complexity that is the true source of worry”. The decision maker's conceptualization of this uncertainty plays an important role in design, adoption and monitoring of these approaches. Giezen (2013) conceptualized uncertainty into three categories: risk, structural uncertainty and unknown uncertainty. Sanderson (2012) adopted the "cognitive approach" for providing alternate explanations to nature of the future in megaprojects. This involves two categories of risks and uncertainties. Risk Category - 1 is mathematically derived probability while Risk Category - 2 is based on empirical data about a certain class of events in the past. Uncertainty Category - 1 is based on the decision makers’ beliefs or expectations grounded in subjective probability of various possible future events or outcomes; it is also called “known unknowns”. Uncertainty Category - 2 describes the situation in which the nature and range of future events or outcomes is unknown and unknowable and is called “unknown unknowns”.

The decision maker’s obvious step after identifying and understanding the complexities associated with a megaproject is the design of treatment and/or strategies for management of complexities or governance of megaprojects. Researchers have typically viewed megaprojects through the lens of “governance”, and show two streams of thoughts for governance mechanisms for managing complexities faced by megaprojects. There is significant similarities between the concepts proposed by Sanderson (2012) and Giezen (2013). Risk refers to Risk Category - 1 and Risk Category - 2 while structural and unknown uncertainty refers to Uncertainty Categories -1 and 2 respectively. Risk as mentioned by Giezen (2013) and Risk Category - 2 as mentioned by Sanderson (2012) can be dealt with by ex-ante risk analysis and management plan, and adopting various ex-ante measures. The first stream postulates that uncertainties owing to Structured Uncertainty as mentioned by Giezen (2013) and Uncertainty Category - 1 as mentioned by Sanderson (2012) can be managed by design and creation, at the front end of the project, of mechanisms to enhance ex post governability.

The second stream of thought on governance of megaproject has been increasingly gaining importance; it focuses on Unknown uncertainty as mentioned by Giezen (2013) and Uncertainty Category - 2 as mentioned by Sanderson (2012), which can be dealt with by appropriate design and creation at the front end of the project, with a shared culture to encourage collaborative and coordinated behaviour for handling emergent turbulence and uncertainty Giezen (2013) mentions that risk, structural uncertainty and unstructured uncertainty can be managed by adaptive capacity - to respond to change (in the context) and the deadlock (in the process), and the strategic capacity focusing on organization of planning and decision making process.

3. RESEARCH METHODOLOGY

This paper adopts the case study research approach. Yin (2003) mentions that this approach is appropriate when the research does not have control over the events, contemporary phenomenon is being investigated and the form of research question is how and why. Considering the objective of this research study, the research question is: How do complexities influence the implementation of megaprojects and what are the mechanisms adopted for complexity management?

We selected two megaprojects in India to address these questions. Both projects are in urban transportation sector, one being the urban rail project while the other is a sea bridge; the commonality of sector ensured controlling of sector specific variables in the analysis. The data pertaining to these case study projects was collated primarily from the secondary sources like detailed project report, contract agreement, newspaper clippings and websites. We approached the client organizations associated with the megaprojects, although, the officials were reluctant to share exact / factual details of projects citing confidential nature of information. In this scenario, we looked for opportunities of interaction with the key officials involved in these projects during presentation and discussions about these projects in public forum. It assisted in gathering relevant primary data pertaining to project shaping, mechanisms and challenges faced in project execution. However, we relied substantially on secondary data to corroborate the evidences from primary sources of data. We have taken extra care to "triangulate" any facts, figures and evidence from different sources. The next section provides the brief case histories of the two megaprojects, with particular emphasis on mechanisms adopted for management of complexities. Subsequently we have discussed the findings from these cases.

4. BACKGROUND OF CASE STUDIES

Ahmedabad metro project provides metro rail network within Ahmedabad, one of major cities in Gujarat state and India, and connectivity with Gandhinagar, the capital of Gujarat state. The detailed project report for Ahmedabad metro was prepared in the year 2004, however, the concept did not take off owing to challenges in mobilization of financial resources. The Government of Gujarat (GoG) established a dedicated organization - Metro-Link Express for Gandhinagar and Ahmedabad (MEGA) Company Ltd.in the year 2010 for implementing this project. A fresh DPR was prepared in the year 2014 and this was further revised in 2015 owing to change in alignment (DMRC, 2014, 2015). This project is divided into two phases. Phase 1 costs USD 1619.3 million and scope of work comprise of North South Elevated Corridor (18.522 kms) with 15 elevated stations, and East West Corridor with 14.737 km and 6 km of Elevated and underground section respectively and, and 4 underground and 13 elevated stations. The construction work for Phase 1 commenced on March 2012 and is expected to be completed by 2020. The percentage rate contract has been adopted for construction / civil work while rolling stock, fare collection system and other electrical mechanical work have been procured with design, supply, installation and commissioning contract. The funding for Phase 1 is mobilized from Japan International Cooperation Agency (JICA), Government of Gujarat (GoG) and Government of India (GoI). Phase 2 consists of elevated corridor of length 34.59 km and 24 elevated stations, and it provides connectivity to important locations like Gandhinagar, Ahmedabad airport and Gujarat Interntional Finance Tech (GIFT) city. This phase was approved by the GoG in October 2017 and the proposal has been sent to the Central Government for approval and possible funding.

Bandra Woli Sea Link project provides connectivity between Bandra - Western suburb and Worli - Central part of Mumbai - the financial capital of India as well as capital of Maharastra state. The scope of work involved construction of flyover, cloverleaf interchange, approach road improvement and cable stayed bridge. The Government of Maharashtra entrusted this project for execution to Maharashtra State Road Development Limited (MSRDC) - an organization established and fully owned by the Government of Maharashtra. The MSRDC was entrusted with rights for toll collection on sea Link Bridge under build, operate and transfer (BOT) model, for a duration of 40 years. The estimated cost and duration of project was USD 100 million and 3 years respectively. The construction began in the year 2000, however, the project experienced cost and time overruns owing to public litigations, poor progress by contractor, change in consultant and major technical design changes (Government of Maharashtra, 2007). The project was completed at USD 196.31 million and it became fully operational in 2010. The project management services were provided by Sverdup from the year 1999 to 2002, and new consultant - Dar Al-Handasah roped in from year 2003 to 2010. The construction of cable stayed bridge was a vital component of this project and it was executed by Hindustan Construction

Company (HCC) limited. The funding for this project was mobilized from Government of Maharashtra, Mumbai Metropolitan Regional Development Authority, and Market Borrowings.

5. ANALYSIS OF CASE STUDIES

Based on the data available on these projects, a brief write up of project and chronology of events was first prepared. Then, the evidence pertaining to different types of complexities was analysed with reference to complexity framework formulated by He et al. (2015) and governance mechanisms proposed by Sanderson (2012). The case study inquiry focused on two aspects: (1) how are complexities manifested in the megaprojects and (2) What are the strategies adopted for management of these complexities. The first aspect provided indication on views of decision makers, involved in megaprojects, about complexities, based on typology provided by Sanderson (2012) which is Risk Categories - 1 and 2, and Uncertainty Categories - 1 and 2. Further, the second aspect provided indication on strategies followed to deal with these risks and uncertainties. The explanation of these views and strategies is provided in the second section of this paper. The case study evidence, which includes nature of complexity as well as strategies adopted for each factor associated with a complexity are reported in Table 1. This analysis is discussed below.

5.1. TECHNOLOGY COMPLEXITY

The decision makers involved in Ahmedabad metro project sought technologies that had been adopted elsewhere in India and proven. The technological complexity was envisaged as "Risk Category – 2", involving ex ante analysis of different technological options adopted in India as well as worldwide, and finally decision on technology in line with project requirements. Therefore, the technological complexity was contained within the confines of "optimizing", as mentioned by Sanderson (2012), in the Ahmedabad Metro project. The decision makers involved in Bandra Worli Sea Link project, being India's first sea link, were in the unchartered territory of selecting technologies in line with the marine environment of Mumbai. The lack of experience on sea bridge construction in India led decision makers into the cognition of "known unknowns". The technical information was gathered with investigations in the areas of geotechnical, marine, environment and traffic. International experts having expertise in Sea Bridge construction used their prior experience and technical information to arrive at appropriate design and construction process. However, the scenario planning of possible unknown future events was not given due importance and thus, the governance arrangements were not geared to deal with the situation of "unknown unknown". The design changes and consequent changes in construction methods that occurred in the Bandra Worli sea link project resulted in setbacks in completing the project within the existing time deadlines and cost targets.

5.2. ORGANIZATION COMPLEXITY

The organizational complexity in the case study projects was dealt with by the creation of dedicated organizational set up with the aim to create a right mix in house and out sourced human resources to fulfil requirements of project. The power in these project implementation agencies was created not only with supporting institutional framework but also by staffing them with officials from prestigious Indian Administrative Services in key administrative positions and deploying domain experts for discharging technical / engineering roles. The push for "optimizing" the utilization of human resources resulted in the involvement of external experts and consultants, according to the phase of project. However, the capacities for effective utilization of these consultants as well as anchoring the suggestions and services provided by them in overarching project goals were not particularly analysed in the organizational design. The evidence from Bandra Worli Sea Link project shows that the changes in design and project management consulting firm at critical juncture of project as well as adverse implications of suggestions provided by the newly appointed firm were not given due attention. Therefore, project implementation organizations had to create governance mechanism for dealing with "unknown unknown" situations apart from traditional set up focusing on "ex ante analysis" and "known unknowns".

5.3. GOAL COMPLEXITY

The shifting of goal is a common feature of megaprojects and is observed in the case study projects as well. The alignment of Ahmedabad metro was changed providing rationale of increased ridership across new route and avoiding congestion of already congested urban zones as well as land acquisition and resettlements. Changes in the Bandra Worli sea link project occurred due to opposition from fisherman and aesthetic rationale provided by a newly appointed design consultant. Although it cannot be denied that these changes in goal created "value" for associated stakeholders, it is necessary to put in place governance mechanisms for steering through these "unknowns" in the megaprojects. The goal change in the Ahmedabad metro, in terms of alignment change, happened at an early phase of project. Therefore, it forced the project implementing agency to revisit the earlier analysis and detailed project report, and start afresh on meeting financial and technical challenges. The natural outcome of these changes were time overruns and upward spiraling of project costs as well as skepticism among Ahmedabad residents over inordinate delays. It has been observed that collaboration between key government, funding and technical agencies ensured the revision of the detailed project report, tying of required funding and speedy approvals. However, the changes happened at a very advanced stage of project shaping in Bandra Worli Sea link project and disrupted the construction process. Collaborative behavior and coordination were missing in dealing with "unknown unknown" situation faced in Bandra Worli Sea Link project, opening a Pandora's box of issues and problems. Project implementation agencies faced difficulties in keeping the project on course and this resulted in standoffs between contractor and design / project management consultant.

5.4. ENVIRONMENTAL COMPLEXITY

The scenarios in the Ahmedabad metro and Bandra Worli sea link project are different in terms of dealing with complexity. The societal and environmental implications of metro rail project was well thought in the governance mechanism of Ahmedabad metro. The environmental impact assessment report was prepared, although it is not mandatory for metro rail projects in the prevailing environmental regulations. The quires and concerns of the project that affected people were dealt with effectively in the design and construction phase. Therefore, the mechanism was geared, by doing ex ante analysis, to deal with the situation. Bandra Worli sea link project showed lack of this ex ante analysis even though the project was implemented in an environmentally sensitive marine environment. This gap had a spiraling effect on goal and technological complexities, for which governance mechanisms were not designed.

5.5. CULTURAL COMPLEXITY

The Ahmedabad metro project was able to garner unwavering support from politicians and funding agencies owing to silent and key championship provided by bureaucracy. The challenges like changes in route alignment and episodes of malpractices were handled evenhandedly by key administrators. This indicates that that the bureaucracy was, perhaps, well equipped to deal with "unknown unknown" in the project. The Bandra Worli sea link project, on the other hand, was not anchored well enough within the administrative as well as political machinery. This created a sense of helplessness at many junctures in the project execution process.

5.6. INFORMATION COMPLEXITY

It has been seen that the information complexity was not afforded due attention in the case study projects. In the Ahmedabad metro project, steps were undertaken to put in place systems focusing on information exchanges during the operation phase, however, there is a little evidence on how it was handled during the construction phase. A similar scenario is observed in Bandra Worli sea link project, wherein, lack of adequate information affected design, scheduling and contract administration.

Table 1. Complexity Mapping of Case Study Projects

Technology Complexity	
Ahmedabad Metro	Bandra Worli Sea Link
Diversity of technology in project	
• Light capacity metro system to cater PHPDT of 15000 to 25000 • On Grade of Automation (GoA 2) • 750 V DC third rail traction power system • Track system: ballast less on main line and ballasted on depot	• Construction of longest open sea cable stayed bridge • Precast construction • Heavy lifting for relocation of launching trusses • Deep foundation for pier and pylon
Dependence of technological processes	
• Ensured interface between major metro rail systems: track, rolling stock, signaling, telecommunication, traction power and train control • Future expansion of metro was considered, such as conversion of a 3 car train to a 6 car train, signaling system can support up to GoA 4	• Foundation design and construction depended on rock / soil strata • Changes in bridge design had implications on erection technologies • Design changes affected the time and cost performance of project
Interaction between the technology system and external environment	
• Proven technology used, all the technologies were already under operation phase across Indian and International metro rail projects	• Open sea affected the project schedule, supply chain and posed challenges in construction process • Ground stabilization for establishment of pre-casting yard near seashore
Risk of using highly difficult technology	
• Adoption of a stable, tested and reliable metro technologies	• Most of technologies, in the areas of open sea construction, piling, heavy lifting, cable stay, are used for first time either in India or at large scale in India environment
Organizational Complexity	
Number of organizational structures hierarchies	
• Creation of lean yet effective organizational structure with fewer hierarchies • Clarity in hierarchies on the basis of executive, functional and technical decision making powers	• Lean organization structure with executive wing, at higher level, with subsequent divulging powers and roles / responsibilities to functional departments
Number of organizational units and department	
• Created in-house departments based on functional areas and project lifecycle • Design, engineering and programme / project management were outsourced	• Creation of departments in consideration to functional domains like administration, engineering, toll monitoring, land, accounts & finance • Services like design, project management were sourced from market based on project location and requirements
Cross-organizational interdependence	
• Cooperation was required of various governmental arms / departments of urban local bodies, state government, central government • Reliance on general engineering consultant in the areas of design, engineering and project management	• Coordination with state government entities, urban local bodies for effective project implementation • Design and technological innovations in bridge construction resulted in overdependence on design and project management firm as well as contractor
Experience and social background of organization members	

<table>
<tr><td>• MEGA was headed by a senior bureaucrat from prestigious Indian Administrative Services (IAS), having extensive knowledge and influence over bureaucratic and elected arms of governments
• Sectoral knowledge was tapped by the deputation of senior Indian Railway Services (IRS) officials and involvement of consultants having experience in Indian and International metro projects</td><td>• Higher level management comprised senior bureaucrats, representing key state government entities, having extensive knowledge of project implementation
• Professional with relevant functional expertise were hired on tenure / contract basis or deputed from public works department and other state government offices</td></tr>
<tr><td colspan="2">Goal complexity</td></tr>
<tr><td colspan="2" align="center">Uncertainty of goals</td></tr>
<tr><td>• Change in metro route/alignment over project timeline were cited as being caused by economic and technical reasons</td><td>• Change in alignment and design of bridge were cited as being a result of opposition from fisherman and aesthetics considerations.</td></tr>
<tr><td colspan="2" align="center">Uncertainty of project management methods and tools</td></tr>
<tr><td>• Project management of different work packages was carried out by the appointment of general engineering consultant</td><td>• Change of guard in design and project management services were provided by consulting organization
• There were revision of design and construction methods mid-way in the project implementation
• Project shaping and implementation were embroiled by stand offs among participants like client, contractor and consultants</td></tr>
<tr><td colspan="2" align="center">Availability of resources and skills</td></tr>
<tr><td>• Funding was tied up with partners – Gujarat Government, Government of India and Japanese Bank of International Cooperation
• Sourcing of required skills was performed using a combination of strategies like deputation of Indian railway officials, contractual appointment and engagement of consultants</td><td>• Finance was sourced from grant, loan from MMRDA, market borrowings (bonds & term loans)
• Skills were sourced from across the work, as project being first of its kind in India</td></tr>
<tr><td colspan="2" align="center">Diversity of tasks</td></tr>
<tr><td>• Metro construction and operation involved multitude of tasks in the domain of civil, mechanical, electrical, information technology
• Extensive interface with citizens was carried out during construction and operation phase</td><td>• Project involved different construction packages for flyover, cloverleaf interchange, approach road, road improvement and cable stayed bridge
• Construction in the open sea and along shore line posed engineering challenges</td></tr>
<tr><td colspan="2" align="center">Dependence of relationship among tasks</td></tr>
<tr><td>• Sequencing and coordination between different work packages were conducted during the construction phase
• Interface management among metro systems was put in place during the operating phase</td><td>• Coordination of work packages was carried out to put facility in use at right juncture
• Task scheduling and execution was carried out in consideration of monsoon and restriction of marine traffic</td></tr>
<tr><td colspan="2">Environmental complexity</td></tr>
<tr><td colspan="2" align="center">Multiple stakeholder</td></tr>
<tr><td>• Project implementation in urban setting resulting in extensive stakeholder consultation with stakeholders with diverse background and interests
• Involved multiple firms like contractors, subcontractors, and designers</td><td>• Challenges in addressing concerns of Fishermen community, nearby residents, civic groups and NGOs
• Misalignment of views of three key stakeholders – client, consultants and contractor during design and construction phase</td></tr>
<tr><td colspan="2" align="center">Environment of changing policy and regulation</td></tr>
</table>

• Delay in project commencement occurred due to delayed decision over funding mechanism • Alignment changes happened during an advanced stage of project	• Forced to address environmental and societal concerns at advanced stage in the project
Environment of changing economy	
• Route / Alignment change was based on the rationale of reduced demand • Financial assistance from developmental organization was obtained at lower interest rate and longer repayment period	• Increased cost of project and delays caused worries and challenges in terms of mobilization of additional financial resources and forfeiting of toll revenues
Environment of changing nature	
• Environment was affected by metro construction and operation • Environment management was put in place to mitigate environmental hazards	• Construction schedule was at the mercy of monsoon season and sea weather • Alignment shifting by 150 meters towards sea exposed the land reclamation and construction activities to harsh marine environment
Environment of changing technology	
• Advanced technologies were adopted	• Bridge was designed to last 100 years
Cultural complexity	
Multiple participating countries	
• There was involvement of financiers, contractors, suppliers and consultants from across the globe	• Engineers and technicians from different countries like China, Egypt, Canada, Britain, Hong Kong were involved for sea link construction
Project team's trust	
• There was unwavering support by political champions and bureaucrats in project shaping and implementation process	• Questions were raised by contractor over change in design and project management consultant • Disagreements occurred between client / consultant and contractor
Sense of cooperation	
• Key stakeholders were represented in the decision making process • The project was reinforced with championship of political leaders	• Sense of helplessness among administrative machinery for resolution of disagreement and intervention of cabinet committee was sought
Cultural differences	
• Personnel having experience of metro project in Asia / India were involved and a consortium with trusted Indian partners was created	• There were clashes in terms of practices followed between the contractor and project management consultant
Information complexity	
Information uncertainty	
• Detailed project reports were revised based on changed alignment • Establishment of electronic data management system	• Designer and contractors faced challenge in geotechnical, marine and construction engineering
Level of processing information	
• There was no evidence on extensive use of building information modeling (BIM) and other similar platforms • Delays occurred due to underground utilities and land acquisition	• Information asymmetry resulted in reaching common grounds over claims made by contractor as well as project management consultant
Capacity of transferring information	
• Design of metro system ensured seamless interface among metro systems • No evidence on extensive use of BIM and other similar platforms	• No evidence on extensive use of BIM and other similar platforms
Degree of obtaining information	

• Vendors, contractor and client used customized ERP/MIS systems, however, there is little evidence on interface among these systems	• No evidence on common platform for information sharing
Integration of more than one system or platform	
• No evidence on integration of different platform • Fragmented information repositories and processing	• No evidence on integration of different platform • Fragmented information repositories and processing

6. SUMMARY

The analysis of two case studies indicates that complexity is an inherent feature of megaprojects and it is necessary to provide due importance to all types of complexities, as mentioned in the framework developed by He et al. (2015), in planning, design, construction and operation of megaprojects. The factors resulting to complexity are the large-scale, long time span, multiplicity of technological disciplines, number of participants, multi nationality, political interests and interests of stakeholders. These factors were evident in the case study megaprojects. It was seen that the effective implementation of megaprojects depends on putting in place governance mechanisms to deal with these complexities. Overall, decision makers involved in case study megaprojects have viewed the future as "Risk" and responded with ex-ante risk analysis and management. It is important to comprehend dynamic nature or complexity, which transcends from "risk" to "uncertainty". The complexities were effectively dealt with in megaprojects wherein governance mechanisms focused not only on dealing with risks but also uncertainties that were known as well as unknown.

Presently, megaprojects are becoming a common feature of infrastructure development and policies in developing countries. As mentioned by Flyvbjerg (2014), time and cost overruns and extensive - prolonged stakeholder engagement has been hallmark of these megaprojects. Developing countries must put into place, governance mechanisms for managing complexities associated with megaprojects. These mechanisms should strike a right balance between both ex ante analysis, which is designed to deal with risks, and shared culture and collaboration among project participants for managing emergent unknowns. It is very important to anchor these mechanisms in the intuitional culture and practices surrounding megaproject. This research is the first step in the direction of understanding complexity and its management in Indian megaprojects. Future research work can focus on complexity modeling with improved governance mechanisms for megaprojects.

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ANALYSIS OF CONSTRUCTION DELAYS IN MINI HYDROPOWER PROJECTS IN SRI LANKA

Isuru Kasun Abeygunawardana[1], Thilina Laksiri Dissanayake[2] and Nisal Indula Swarnachandra[2*]

[1]Birmingham City University, United Kingdom

[2]Colombo School of Construction Technology, Sri Lanka

ABSTRACT

The share of mini hydropower plants in electricity generation is becoming more important in modern power generation due to the national policy targets to move from the fossil fuel brown energy to sustainable green energy. Therefore, the demand for construction of the mini hydropower plants has become higher but these projects show a significant rate of delays in project delivery. This research was carried out to identify the project delay phases and the main delay factors in mini hydropower projects. Furthermore, it was expected to derive mitigating measures for mini hydropower project delay based on the findings. The data collection process was based on multiple case studies where the project planning documents of three mini hydropower projects were reviewed to extract delay information. Here, projects managers validated the information in the documents to be correct and gave an overview of what has happened during the project. Here all information extracted was discussed under the headings of the case studies (P1, P2 and P3). With information extracted, delays in ten significant phases of the mini hydropower projects were identified with its delay percentages. The most delaying phase of the mini hydro project was the weir construction while least being the fore-bay construction. Delays in hydropower projects occur mainly due to the natural consequences such as adverse weather conditions and environmental conditions such as an earth slip. Protests by the interested parties were the next major concern when it comes to delays in mini hydropower projects. Proper management of the identified delay factors and awareness of delays in relevant phases is required. Nevertheless, it was found to be essential to make the interested parties fully aware about the environmental impact even before the initiation of the project in order to successfully mitigate the significance of delays.

Keywords: *Construction Delays; Delay Mitigation Methods; Mini Hydropower Projects.*

1. INTRODUCTION

The government of Sri Lanka carries out larger power generation projects and projects that are less than 10MW capacities have been permitted to the private sector, since this permission is being allowed many private companies have shown interest in investing in hydropower projects (Wijenayake, 2016). According to Hisham and Yahya (2016), most critical problem that may occur in any construction project is delays, and authors further discuss that there is a correlation between the causes of delay and the effects on the project. Howard (2016) has mentioned that delay is no exception for the hydropower projects and that the project net present value of the investment will be affected due to delays. Moreover, Kesavan et al. (2015) state that if the project's objectives are disrupted that will certainly contribute to project delays with in turn will render adverse effects on project objectives. Delay causing incidents may include weather, unavailability of resources and design delays. However, Vidalis and Najafi (2002) is of the view that project delays occur as a result of external and internal causes and effects related to different phases of construction. According to Sambasivan and Soon (2007) the delays will lead to considerable negative effects such as lawsuits between owners and contractors, loss of productivity and revenue. Therefore, irrespective of the project types, its inevitable delays have to be identified and minimised for the project to achieve the desired objectives.

*Corresponding Author: E-mail – nisalindula132@gmail.com

Internationally there are many types of research carried out in order to find out the most significant causes of delays in construction projects to be aware of mitigation methods to minimise the delays. Identifying the causes of the delays is the first step when addressing a problem therefore; the corrective action can be taken (Aibinu & Odeyinka, 2006). According to a research which was conducted by the Stoy et al. (2007) in Germany, the efficiency of the construction depends on the geographical location of the project, type of the construction project and the methods of the project conducting such as turnkey project and traditional project. Agreeing to the fact that type of construction project will attribute to the efficiency of the project, Manders et al. (2015) had further considered small-scale hydropower station (hydel) as a strategically important species of construction which has to be more sensitive to the environment. The authors also emphasise that the selection of location and quantification of its effects to the project is vital in reducing errors in these types of projects done in extreme environments.

2. LITERATURE REVIEW

Presently, over 15 companies in private sector are engaged in mini hydro-power projects and supply 307 MW of power to the national grid from 154 mini hydro-power plants which amount to 17.5% of hydropower generation in the country (Ceylon Electricity Board, 2015). The Ministry of Power and Energy stated that they anticipate utilising all possible locations to contributing of 873 MW of power by the year 2020 by constructing mini hydropower plants (Ministry of Power & Energy, 2015). These factors emphasise that the mini hydropower industry is a growing industry. However, Colombo Business Reporter (2017), has mentioned in their article that the communities who are the dependents of river water are of the fear that once the water is harnessed by the hydropower projects, they might not get the same benefits as before, therefore it has been a hindrance factor for the development of mini hydropower projects in Sri Lanka and its potential is yet to be maximized.

Manders et al. (2015) stated that every construction project has unique delaying factors according to nature of the project, it is correct for the mini hydropower construction industry as well. In addition, the strategies for the causes given in the aforementioned research were mainly concentrated on the environmental concerns and the researchers have focused on water flow dynamics, where the changing environment context becomes much important in mini hydropower construction. Williams (2003) has stated that delays can be occurred due to the faults of the Client, Contractor and the Consultant, due to the fact that they have not correctly figured out the context and the special requirements of the project. Therefore, it makes the argument certain that apart from the traditional delays applicable for other construction sectors, project specific delay factors are applicable in the mini hydropower project context.

Howard (2016) had mentioned referring to the hydropower projects and mentioned that delays in those projects are of two types. Those are technical and non-technical delays. Technical delays relate to the engineering and commercial problems, while non-technical delays relate to environmental and social factors, community issues, and health and safety challenges. The researchers also of the view that, even though the technical delays can be minimised to an extent, the non-technical delays will affect the project progress in a significant way, in fact, 54% of all delays. Pathiranage and Halwathura (2010) had emphasised in their research on road construction that delays could happen from the initiation of the construction to the completion due to various reasons and some of them are delays are unique to each phase. When considering the two views, it can be hypothetically considered that even in hydropower projects delays can be analysed related to different phases of the construction. During this research, hypothesis was established through various literature by identification of major causes for delay according to the literature review (Table 1).

According to Table 1, it can be inferred that many of the delay factors are due to the poor coordination between the client/consultant and the contractor. Apart from the poor coordination inefficiency of the client and the contractors, has delayed the projects from time to time. Moreover, financial issues have also made concern while getting the project into realisation. Apart from these factors, other major concern had been adverse weather condition which has halted the projects from time to time. This was seconded in a Sri Lankan research where Jayawardena and Panditha (2003) emphasise that the main factor of delay in Sri Lankan construction projects is due to the rainy weather conditions. While identifying that the rainy weather as the main cause of delay in a tropical country like Sri Lanka, the abovementioned researcher identified that the next most concerning delay factor as the manpower shortage satisfying the requirements of the project. Mudge (2016) has made his views clear with the fact that except for the weather conditions all other factors can be minimised simply by being aware of them and creating a contingency plan upfront. Even though Mudge (2016) is silent on the manpower shortages he identifies that proper collaboration between the client and the other stakeholders can be extracted into a contingency plan, which in turn will minimise most of the factors of delay.

Table 1: Delays in Construction projects

Delay factors identified	Reference
Contractors improper planning, Contractors improper site management, inadequate contractor's experience, Problems with subcontractors, Shortage of material, labour supply, Equipment availability and failure, Inadequate client's finance and payments for completed work, lack of communication between parties and mistake during the construction stage.	(Sambasivan & Soon , 2007)
Financing projects by contractors during construction, delay in contractor's payment by owner, design changes by owners during construction, partial payments during construction, non-utilization of professionals during construction and construction management.	(El-Razek et al., 2008)
Approval of shop drawings, delays in payment to contractors and the resulting cash problems during construction, design changes, conflicts in work schedules of subcontractors, slow decision making and executive bureaucracy in owner's organizations, design errors, labour shortage and inadequate labour skills	(Assaf et al., 1995)
Inadequate feasibility studies, errors and omissions in detail designs, improperly harmonized procurement documents, shortcomings in the contract document, stakeholder identification and management issues, Variation and scope changes, land acquisition and resettlement, extreme weather	(Jeykanthan & Jayawardena, 2012)
Natural disasters like flood and earthquake, financial problems of the clients, improper planning, poor site management, poor experience of labours and lack of materials and equipment	(Haseeb et al., 2011)
Poor risk management and supervision, unforeseen site conditions, slow decision making, client-initiated variations and work variations	(Chan and Kumaraswamy, 1996)
Change orders by owners during construction, Delay in progress payment by owner, Ineffective planning and scheduling of projects by contractor, Poor site management and supervision by contractor, Shortage of labour, Difficulties in financing project by contractor	(Assaf, & Al-Hejji, 2006)
monthly payment difficulties, poor contract management, material procurement, inflation, contractor's financial difficulties, escalation of material prices, cash flow during construction, planning and scheduling difficulties, bad weather, deficiencies of cost estimate prepared	(Fringpong et al., 2003)
Delay in delivery of materials to the site, shortage of materials, poor skills and experience of works, shortage of site labour. delayed and slow supervision in making decisions, poor weather conditions	(Alaghbari et al., 2007).

3. RESEARCH METHODOLOGY

The probable delay factors of mini hydropower projects which were identified through the literature survey had to be tested by already completed mini hydro projects. Therefore, multiple case study research method was found to be the most convenient method to arrive at conclusions. In order to meet the requirement three cases (projects) of the similar difficulty was selected, and work programmes of those cases were reviewed and later validated by the project managers, to generate more reliable results regarding the construction delays visible in mini hydropower projects.

The data collection was started by finding areas where the mini hydropower plants highly situated and found. Companies who construct mini hydropower plants, with the help of Google search engine. According to the requirement, the three projects were selected with similar difficulty in location and other specifications. Following Table 2 provides the location and technical specification of selected projects (P- Represents the word "Project").

Table 2: Technical Specifications of Mini Hydropower Plants

Project	(P1)	(P2)	(P3)
Location	Neluwa	Morawaka	Kuruwita
River Catchment	Gin Ganga	Nilwala Ganga	Kuru Ganga
Project Capacity (MW)	2.5	2	2.6
Mean Annual Energy Supply (GWH)	10.2	8.23	11.21
Channel Length (m)	660	225	1700
Penstock Length	40	68	140
Number of Turbines	2 @ 1250 KW	2@ 650, 1@ 700	2@ 650, 1@ 700
Weir Length	30	50	30
Weir Height (Av.)	2.5	1.8	2.5

Afterwards site visits were arranged to obtain details about the site and work program by getting approval from the client of the selected projects. Extracted details from the project planning documents were validated to be correct by the project managers at the site visits and made a list of delaying factors in each phase. Finally, the probable delay mitigation methods were also derived with the delayed phases with the assistance of the respective project managers for the abovementioned projects.

4. RESULTS AND DISCUSSION

The data analysis was based on three case studies as given above, data extracted from the planning schedules and programmes and the reason for the delay is tabulated as below (Tables 3 and 4).

Table 3: Delay Percentages and Reasons for Delay

Activity**	P1			P2			P3		
	Delay (days)	%*	Reasons for delay	Delay (days)	%*	Reasons for delay	Delay (days)	%*	Reasons for delay
Weir Access and road construction	4	11	Obstructions from NGOs and neighbors.	3	12	Obstructions from NGOs and neighbors.	7	21	Objections from neighbors
On ground access road construction	8	47	Labor shortages, Lack of skilled labors, poor supervision and obstructions from NGOs neighbors.	11	33	Obstructions from NGOs and neighbors.	15	22	Objections from neighbors, labor shortages.
Intake construction	25	20	Labor shortages, Lack of skilled labors, adverse weather condition (flooding) and design changes.	98	73	Labor shortages, Lack of skilled labors, obstructions from NGOs, local politicians, neighbors and Central Environmental Authority. design changes	6	5	Poor supervision, Lack of skilled labors and materials late delivery

Desisting structure and channel on ground	10	7	Material late delivery, bad weather (heavy rain and earth slip) and design changes.	15	11	Bad weather (heavy rain), Material late delivery, obstructions from NGOs, local politicians, neighbors and Central Environmental Authority and management issues.	5	4	Bad weather (heavy rain) and Material late delivery.
Weir construction	20	29	Adverse weather Condition (flooding) and design changes.	52	72	Obstructions from NGOs, local politicians, neighbors & Central Environmental Authority. Design changes due to location changes and management issues.	8	11	Bad weather (heavy rain).
Aqueduct column construction	8	31	Unforeseen ground conditions	4	29	Unforeseen ground conditions.	23	44	Unforeseen ground conditions and bad weather condition (earth slip) and design changes.
Aqueduct channel section			No Delay			No Delay	16	11	Bad weather condition (earth slip) and design changes
Fore bay construction			No Delay	3	2	Material late delivery.			No Delay
Power house construction	13	4	Unforeseen grounds conditions and objection from neighbours and irrigation department.	9	3	Unforeseen grounds conditions, poor supervision and objection from neighbours.	15	5	Unforeseen grounds conditions bad weather condition (flooding), labour shortages and poor supervision.

*Delay percentages compared to the planed duration.

4.1. *IDENTIFIED DELAYING FACTORS AND THE PERCENTAGE CHANGE IN DURATION*

According to the analysed data of the three case studies, many delaying factors agreed with the literature survey. Analysed delaying factors of the case studies can be categorised as external factor sand internal factors. External factors were identified to be bad weather condition, objections from protestors, objections from government authorities and unforeseen ground conditions. Internal factors were identified to be management issues, late delivery of materials, labour shortage, and lack of skilled labours, design changes, and poor supervision.

During the validation process with the project managers, it was identified that the most common and the most harmful delaying factor for mini hydropower projects as adverse weather conditions. This was suggested to be minimized through proper site investigation followed by analysing previous weather reports, flooding reports, geological reports of the site area and identifying the suspicious places which are having a tendency for an earth slip before designing.

The second major problem identified was the objection from the protestors such as neighbours, local politicians, NGOs and environmentalists and objections from the government authorities. Mainly, their objections were arisen due to the unawareness of the project. This can be minimised by community awareness programs before commencing the project. Neighbours objection also had occurred due to the noise while blasting the rocks for the excavation and while taking off the lands. By limiting the blasting into the limited time, the objection can be mitigated from the neighbours due to the noise.

The third extensive delay factor was identified to be the unforeseen ground condition according to the research. Before making schedules, the ground condition must be identified otherwise sufficient time cannot be allocated for the ground works. This can be minimised by doing soil investigation and by referring the geological reports of the project area.

4.2. *IDENTIFIED DELAYING PHASES IN MINI HYDROPOWER PROJECTS*

Project activities were ranked according to the delay percentage compare to the planned duration of the activities and the data was entered to Table 4.

Table 4: Ranking of the Activities According to the Extent of the Delay and Delaying Causes

Activity	Mean %*	Rank	Cause of Delay
Weir access road construction	14.8	5	Obstructions from NGOs and neighbors.
On ground access road construction	33.4	3	Labor shortages, Lack of skilled labors, poor supervision and obstructions from NGOs neighbors.
Intake construction	32.6	4	Bad weather, Poor supervision, Lack of skilled labors, materials late delivery, obstructions from NGOs, local politicians, neighbors and Central Environmental Authority, design changes, intake location changes and management issues.
Desisting structure and channel on ground	7.4	7	Bad weather (heavy rain, flooding, earth slip), Material late delivery, obstructions from NGOs, local politicians, neighbors and Central Environmental Authority and management issues.
Weir construction	37.2	1	Bad weather, Obstructions from NGOs, local politicians, neighbors and Central Environmental Authority, design changes due to weir location changes and management issues.
Aqueduct column construction	34.7	2	Unforeseen ground conditions and bad weather condition (earth slip) and design changes.
Aqueduct channel section	11.5	6	Bad weather condition (earth slip) and design changes
Forebay bay construction	2.2	10	Material late delivery.
Powerhouse house construction	3.8	8	Unforeseen grounds conditions bad weather condition (flooding), labor shortages and poor supervision. Objection from neighbors.
Penstock Laying	3.1	9	Poor supervision

According to the ranking, most delayed activities were weir construction, aqueduct column construction, on ground access road construction and Intake construction in the mini hydropower plant construction.

According to the above analysis, weir construction was found to be the phase where the most attention should be given in terms of delay; the obstructions from external parties have been the main issue. Moreover, the weir construction is done directly across the river and thereby interested parties' involvement becomes more prominent. Aqueduct column construction was found to be the next concern phase of the construction. However, aqueducts are not constructed necessarily on top of columns most parts of the considered projects were constructed on the ground as channels; therefore, the delay would not affect the overall delay of the project in a considerable scale.

Access roads to initiate the project was the third most prominent delay phase in mini hydropower construction, this was mainly due to the labour shortages and material supply delays, this is common due to the fact that it is the beginning of the project and the resource allocation has not been properly done. Especially in the given adverse environment, it is difficult to find appropriate labour. Intake construction was the next concern delay phase. What have affected the intake construction have been the external factors. Internal factors also have influenced in terms of the design changes which happen once the construction has begun. Other phases in mini hydropower construction have very low delay percentages. However, those delay factors identified have to be addressed, as the total duration of phase will change with the project scope.

5. CONCLUSIONS

In this multiple case study, an attempt was made to identify the important delaying factors of the mini hydropower construction, and mitigate measures were proposed concerning the mini hydropower plants in construction industry of Sri Lanka to mitigate the delays and its impacts on the time, cost, quality and the safety of the project. The study revealed that the adverse weather condition, objection from protestors and government authorities, and unforeseen ground conditions are the most significant delay factor among the three case studies. Moreover, weir construction, aqueduct column construction, on ground access road construction, and intake construction were the most delayed phases of the mini hydro power plant construction according to the research findings.

Based on the extracted information of this study, few recommendations can be made to mitigate the causes of delays which can be attributed to the clients and contractors with respect to mini hydropower plants construction projects in Sri Lanka. It seems to be important that the client will have to make measures to educate the villagers, local politicians, NGOs and environmentalists about the project clearly and the advantages of the project to the country and the villagers before starting the project. Even though the adverse weather cannot be addressed lack of proper management with weather schedules, also had increased the severeness of delay. Moreover, it was found that proper site investigation should be done to mitigate the structure break down due to earth slips, this is important due to the challenging environmental conditions where hydro power plants are situated.

Additively, attention must be focused on the weir construction, aqueduct column construction, on ground access road construction and intake construction; thereby the contractor has to be informed to take extra care in these phases. Interestingly the delays observed in these phases had some relation with the technicality/ difficulty of workmanship. Frequent design changes in the weir construction, aqueduct channel and the intake construction is an evidence of that fact. However, overwhelming the technical difficulty, other common delays like weather conditions and objection from third parties have affected the delay in these phases as well.

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APPLICABILITY OF GREEN ROOFS IN SRI LANKAN HIGH-RISE BUILDINGS: DRIVERS AND BARRIERS

Charles Subaskar*, Herath Vidyaratne and D.G. Melagoda

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Sri Lanka is experiencing a construction boom and there are many high-rise building constructions coming up. Thus, many adverse effects are associated with high rise buildings. Greenery provides several benefits to the environment and reduces these effects. However due to limited space in urban areas it is impossible to plant new plants, trees and vegetation around the buildings. As a solution green roofs can be adopted as they provide many environmental and sustainable benefits from rooftops. Though this concept is more popular across many countries over the past few decades, still implementation of this technology in Sri Lanka is new and scant. Due to the lack of past researches, awareness on green roofs is very low for professionals, developers, government authorities, building owners and general public.

The aim of this research is to identify and analyse the potential of green roofs in high rise buildings in Sri Lanka. A comprehensive literature review was carried out on popularity of green roof in global context, types of green roofs, components of green roofs, barriers and drivers in implementing green roofs. The data collection was conducted through expert interviews and questionnaire survey. Expert interviews were carried out to validate the barriers and drivers identified through literature review in Sri Lankan context and questionnaire survey was used to identify the most significant barriers and drivers. Purposive sampling techniques was used for selection of the respondents. The data collected from expert interviews were analysed through manual content analysis and the data collected by questionnaire were analysed using RII method. The final outcome of this study finds that green roof is an applicable concept for Sri Lankan high rise buildings.

Keywords: *Barriers; Drivers; Green Roofs; High Rise Buildings.*

1. INTRODUCTION

Globally buildings are responsible for 40% of the total world annual energy consumption (Kamarulzaman, et al., 2014) and increasing of energy consumption due to global warming issues have attracted the awareness of researchers, architects, engineers, property developers, facilities managers and authorities to the crucial of green construction or sustainable development concepts (Sheweka and Mohamed, 2012). Sri Lanka is currently experiencing a construction boom due to increased interest of investors after the end of a three decade-long conflict and restoration of peace (Karunasena, Rathnayake & Senarathne, 2016) However, major adverse effects can be identified associated with high rise building construction activities on environment such as greenhouse gas emissions into air, waste generation, soil pollution, water spills, high consumption of resources, impacts associated with transportation and effects on biodiversity (Gangolells, et al., 2009).

There are different strategies to mitigate the negative impacts of urbanization (Moghbel & Erfanian, 2017). One of the most effective strategies is conversion of impervious surfaces in urban areas into a multifunctional land cover such as vegetated roofs or green roofs (Carter & Butler, 2008). There are many descriptors for green roofs, including intensive/extensive, living roofs, garden roofs, eco roofs, vegetated roof tops and high-maintenance/low-maintenance roofs (Barreiro, 2012). This technology is more popular across Europe over the past few decades in countries like Switzerland, France (Zhang, et al., 2012), United Kingdom (Oberndorfer, et al., 2007) and Portland (Townshend & Duggie 2007) and as well as other many countries such as USA (United

*Corresponding Author: E-mail - subaskar.charles23@gmail.com

States of America), Canada, Australia, Singapore, Japan (Vijayaraghavan, 2016) and Hong Kong (Zhang, et al., 2012). In contrast, implementation of this technology in other developing countries is still new and scant (Blank, et al., 2013).

2. LITERATURE REVIEW

2.1. INTRODUCTION TO GREEN ROOFS

Green (vegetated) roofs are globally accepted technology which has the potential to help mitigate the complex environmental problems of urban centres (Clark, Adriaens & Talbot, 2008). As mentioned by Dunnett and Kingsbury (2004) green roof is a planted roof or a roof that consists of vegetation and growing medium. It uses plants ranging from grass, trees, moss, flowers lichen, sedum, shrubs, and bushes. In addition to their ecological characteristics, green roofs can improve the life of the roof and provides a fully functioning roof (Kamarulzaman, et al., 2014). Although green roofs are initially more expensive to construct than conventional roofs, they can be more economical over the life span of the roof for the reason that energy saved and long life of roof membranes (Porsche & Kohler, 2003). Moreover, they act positively upon the global warming and climate of the city and its region as well upon the interior climate of the buildings beneath them. According to Velazquez (2005), combining plants with architecture is not a new idea, and neither are green roofs. Planting vegetation at the building rooftop is an old technique (Vijayaraghavan, 2016). The earliest documented roof gardens were the hanging gardens of Semiramis in what is now Syria, considered one of the seven wonders of the ancient world (Oberndorfer, et al., 2007). Green roof can be divided into two distinguished types such as extensive green roofs and intensive green roofs.

2.2. COMPONENTS OF GREEN ROOFS

A green roof comprises of a waterproofing membrane, a root barrier, drainage layer, filter layer, substrate and plants. A waterproofing membrane sits immediately on top of the structural roof deck as an insulation to prevent moisture from entering the building (Vijayaraghavan, 2016). Typically, a root barrier layer is designed to prevent roots from penetrating the waterproofing membrane and the structural roof (Bianchini & Hewage, 2012). The drainage layer is the next and it protects water proof membrane too and improves thermal properties of green roof (Townshend & Duggie 2007). Filter layer separates the growth substrate from the drainage layer and prevents small media particles from entering and clogging the drainage layer below. The next components are substrate and plants. Green roof substrates need to be lightweight, physically and chemically stable, hold adequate amounts of water and nutrients for plant survival (Rowe, Monterusso & Rugh, 2006). A green roof uses plants ranging from grasses, mosses, lichens, sedums, trees, shrubs, flowers and bushes (Weiler & Scholz-Barth, 2009).

2.3. DRIVERS FOR GREEN ROOF SYSTEM

Several authors explained that green roofs provide many economic and environmental benefits which act as drivers for adopting green roof retrofit.

Table 1: Drivers Identified from Previous Studies

Drivers	**Sources**																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Reduce Urban Heat Island effects									√				√				
Thermal benefits and energy savings				√		√								√		√	
Storm water management					√					√	√			√			
Better run-off water quality	√		√														
Reduce air polution							√	√						√	√		
Noise reduction		√															√
Green rating system												√			√		
Aesthetical appearance												√			√		

1 - Barreiro (2012), 2 - Connelly & Hodgson (2013), 3 - Getter & Rowe (2006), 4 - Hashemi, Mahmud & Ashraf (2015), 5 - Mentens, Raes & Hermy (2006), 6 - Niachou et al. (2001), 7 - Pandit & Laband (2010), 8 - Rowe (2011), 9 - Santamouris (2014), 10 - Speak et al. (2012), 11 - Stovin, Vesuviano & Kasmin (2013), 12 - Velazquez (2005), 13 - Vijayaraghavan & Raja (2015), 14 - Vijayaraghavan (2016), 15 - Wilkinson & Reed (2009), 16 - Wong et al. (2003), 17 - Yang, Kang & Choi (2012).

2.4. BARRIERS FOR GREEN ROOF SYSTEM

There is a lot of discussion in research literature on different benefits and challenges of green roof systems (Williams, Rayner & Raynor, 2010). Even though research reports and environmentalists attempt to highlight positive aspects of the green roofs, several factors hinder the growth of green roofs as well (Vijayaraghavan, 2016). To improve comparative benefits and bring about advocated green change, researchers need to answer and find solutions regarding the barriers and challenges related to usage and acceptance of green roofs (Williams, Rayner & Raynor, 2010).

Table 2: Barriers Identified from Previous Studies

Main Factors	References	Main Factors	References
1. Cost	Vijayaraghavan (2016), Bianchini & Hewage (2012), Carter & Keeler (2008), Jim (2011), Duda (2009), Peri, et al. (2012)	2. Lack of awareness and research	Blank et al. (2013), Wong & Lau (2013), Vijayaraghavan (2016), Kibert (2016)
3. High amount of maintenance	Nagase, Dunnett & Choi (2013), Vijayaraghavan (2016)	4. Lack of support from government	Williams Rayner & Raynor (2010), Steven & Ireen (2003), Zhang, et al. (2012)
5. Lack of support from building owners	Vijayaraghavan (2016), Hwang & Tan (2012)	6. Lack of technical competence	Zhang, et al. (2012), Thwala & Mvubu (2008)
7. Space allocation on roof tops	Duda (2009), Zhang, et al. (2012)	8. Concern on disposal of green roof components	Vijayaraghavan (2016), Peri et al. (2012)
9. Lack of green roof, materials and suppliers	Williams, Rayner & Raynor (2010), Vijayaraghavan (2016)	10. Lack of human resources	Zhang, et al. (2012), Hwang, Zhu, L & Tan (2017)
11. Uncertainty and risks	Duda (2009), Sailor (2008), Dunnett & Kingsbury (2004)	12. Lack of plants	Williams, Rayner & Raynor (2010), Snodgrass & Snodgrass (2006), Monterusso et al. (2002)

3. RESEARCH METHODOLOGY

Research approaches are classified mainly in to two as quantitative and qualitative (Fellows & Lui, 2015). This study uses both quantitative and qualitative approaches. Expert interviews and questionnaire survey method have been identified as the most appropriate approach for this research. Expert interviews were carried out to identify the main factors which act as drivers and barriers in implementing green roof technology in Sri Lankan context. Then a questionnaire survey was conducted to identify the most significant drivers and barriers out of the drivers and barriers identified through literature review and experts interviews. Each identified barrier and driver is assigned a score based on a one to five point Likert's scale. The respondents were invited to give their opinion on the relative significance of each barrier which hinder and drivers which motivate the implementation of green roof systems. The respondents were invited to judge the significance degree of each listed barrier, with grading "1" as strongly disagree, "2" being disagree, "3" being neutral, "4" being agree and "5" as strongly agree. After that again expert interviews were carried out to identify the ways to overcome the most significant barriers. The sampling technique used in this study is purposive sampling. The reason for the purposive sampling method is that there are only few expertise in green roofs in Sri Lanka. Data collected from expert interviews was analysed through manual content analysis and questionnaire survey was analysed through relative important index.

4. DATA ANALYSIS AND FINDINGS

4.1. FINDINGS OF THE EXPERT INTERVIEWS

Table 3: Profile of the Respondents of Expert Interviews

Code	Designation	Experience
R1	Architect	15-20 years
R2	Architect	10-15 years
R3	Engineer	15-20 years
R4	Engineer	5-10 years
R5	Green Cosultant	5-10 years
R6	Facility Manager	10-15 years
R7	Facility Manager	15-20 years

All experts agreed that green roofs can be applicable in Sri Lanka and R1-R6 agreed that green roofs can be applicable in Sri Lankan high rise buildings. R7 stated that green roofs cannot be applicable in high rise buildings due to the space constraint. He explained his point by stating that the roof top area in many high rise buildings are mostly occupied for building services such as chiller plants, cooling towers, telecommunication antennas and swimming pools. Therefore, there is no much space left for green roofs in high rise buildings. He accepted that green roofs can be applicable in Sri Lanka for low rise wider buildings. Experts who agreed on applicable of green roofs in high rise buildings gave their opinions on drivers and barriers for green roofs in Sri Lankan context. The factors which are accepted by 4 or more than 4 respondents are included in the questionnaire survey.

From the literature review eight factors were identified as drivers. Through the expert interviews additionally three factors were identified which are “bio diversity”, “increased roof life and property value” and “better Indoor Environmental Quality and well-being of people”. When it comes to barriers, twelve barriers were identified through literature review. Experts identified eleven factors as significant barriers in Sri Lankan context and rejected “lack of plants” as a barrier. From the point of experts, there are variety of plants available in Sri Lanka and only the problem is lack of professional experts to advise on the selection of suitable plants according to the type of green roof, location and climate conditions.

From the discussion, points and explanation of the experts, out of the final eleven factors six factors were divided into sixteen sub factors. Two factors which are technical competence and lack of human resources were merged and divided into three sub factors. Three factors were not divided into sub factors. All together 22 sub factors were identified and included in the questionnaire.

Table 4: Categorization of Main Factors and Sub Factors

No	Main Factor	No	Sub Factors
1	Cost	1	High construction cost
		2	High maintenance cost
		3	Opportunity cost
2	Lack of awareness and research	4	Lack of research on environmental and economic benefits of green roof
		5	Lack of awareness
3	High amount of maintenance	6	High amount of maintenance
4	Lack of support from government	7	Lack of government policies and regulations
		8	Lack of government incentives and promotions
5	Lack of support from building owners	9	Lack of support from building owners

6 7	Lack of technical competence Lack of human resources	10 11 12	Lack of experienced professionals Lack of experienced installers Lack of experienced maintenance staff
8	Space allocation on roof tops	13	Space allocation on roof tops
9	Concern on disposal of green roof components	14 15	Environmental considerations on disposal of the components Cost and man power needed for disposal of the components
10	Lack of green roof, materials and suppliers	16 17	Lack of green roof components suppliers Lack of green roof plants and growing media suppliers
11	Uncertainty and risks	18 19 20 21 22	Fire risk Financial risk Climate and PESTs Weed spread Risk of failure

4.2. *FINDINGS OF THE QUESTIONNAIRE SURVEY*

After identifying the drivers and barriers in Sri Lankan context through expert interviews, a questionnaire survey was conducted to identify the most significant drivers and barriers and at the same time respondents were asked the applicability of green roofs in Sri Lanka and in Sri Lankan high-rise buildings. Out of the 54 professionals who received the questionnaire, 38 professionals responded representing 70.4 % responding rate. All the professionals were well experienced in green concepts and familiar with green roofs. Above 70% of the respondents had more than 5 years post qualification experience, indicating that those surveyed were well experienced built environment practitioners.

Table 5: Profile of the Respondents of Questionnaire Survey

Categorisation	Details	No.	Percentage
Profession	Architects	16	42%
	Engineers	11	29%
	Quantity surveyors	4	11%
	Facility Managers	7	18%
Experience	0-5 years	10	26%
	6-10 years	14	37%
	11-15 years	6	16%
	More than 15 years	8	21%
Sector	Private	22	58%
	Public	10	26%
	Academic	6	16%
Familiarity with green roofs	Very familiar	24	63%
	Familiar	8	21%
	Slightly familiar	6	16%

When it comes to the applicability of the green roofs in Sri Lanka, all the 38 respondents agreed (100%) that green roofs can be applicable in Sri Lanka while when it comes to the applicability in high-rise buildings 34 (89%) out of the 38 respondents agreed. Out of the 34 respondents 32 respondents have experience of more than 5 years. The respondents who agreed that green roofs are applicable in Sri Lankan high-rise buildings (34 respondents) were invited to judge the significance of each listed driver and barriers according to Likert scale.

Table 6: Final Ranking of the Drivers Through Questionnaire Survey

Drivers for successful implementation of green roofs	No of respondents and their points					RII	Ranking
	1	2	3	4	5		
Reduction of air pollution	0	0	0	13	21	0.826	1
Aesthetical appearance	0	0	0	19	15	0.795	2
Thermal benefits and energy savings	0	3	2	14	15	0.753	3
Reduce Urban Heat Island effect	0	2	4	15	13	0.742	4
Points in green rating system	0	0	1	28	5	0.737	5
Better IEQ and well-being of people	0	0	13	18	3	0.663	6
Biodiversity	0	0	21	13	0	0.605	7
Noise reduction	0	1	20	13	0	0.6	8
Increased roof life and value of property	0	7	16	11	0	0.558	9
Storm water management	0	6	14	13	0	0.558	9
Better run-off water quality	1	9	16	4	0	0.437	11

Reduction of air pollution is ranked as first driver of green roofs in Sri Lanka with RII value of 0.826. There is limited space in Sri Lankan urban areas and green roofs make it possible to plant plants and vegetation in roof tops. Green roofs provide opportunity to reduce the negative impact of carbon dioxide and produces oxygen and filters the air. Airborne particulates are caught within the vegetation and the pollutants are filtered naturally through the planting systems. Aesthetical appearance is the second most significant driver as green roofs offer people to spend their leisure time with relaxing and eye-catching view at their roof top and this reduces stress. The third significant factor is thermal benefits and energy savings as green roofs reduce the heat transferred from the sun to the buildings. This creates a cooler environment and the need of air conditioning is reduced. Green roofs have more contribution towards reducing UHI effects as they are on the roof top. The heat transferred to the lower part of the building is low. As a reason reducing UHI effects has been ranked as fourth driver. The least significant factors are storm water management and better run-off water quality as they are not suitable for high rise buildings in Sri Lanka. In low rise buildings green roofs can offer better storm water management and better run-off water quality.

Table 7: Final Ranking of the Barriers through Questionnaire Survey

Barriers for successful implementation of green roofs	No of respondents and their points					RII	Ranking
	1	2	3	4	5		
Lack of awareness	0	0	0	11	22	0.811	1
Lack of space on roof tops	0	1	2	9	22	0.810	2
Lack of experienced professionals	0	0	1	16	17	0.8	3
Lack of experienced installers	0	0	0	25	9	0.763	4
High construction cost	0	1	2	22	9	0.742	5
Opportunity cost	0	0	12	21	1	0.737	6
Lack of research on environmental and economic benefits of green roof	0	0	1	28	5	0.737	6
Lack of support from building owners	0	0	9	16	9	0.716	8
High amount of maintenance activities	0	0	2	32	0	0.705	9
Lack of government policies and regulations	0	0	10	19	4	0.663	10
Fire risk	0	0	11	23	0	0.658	11
Climate and PESTs	0	0	12	22	0	0.658	11
Financial risk	0	0	13	21	0	0.647	13
High maintenance cost	0	1	12	21	0	0.642	14
Weed spread	0	0	16	18	0	0.632	15

Barriers for successful implementation of green roofs	No of respondents and their points					RII	Ranking
	1	2	3	4	5		
Risk of failure	0	0	17	17	0	0.626	16
Lack of government incentives and promotions	0	2	12	19	0	0.611	17
Lack of experienced maintenance staff	0	0	23	11	0	0.595	18
Lack of green roof components suppliers	0	9	14	11	0	0.547	19
Environmental considerations on disposal of the components	0	8	26	0	0	0.495	20
Lack of green roof plants and growing media suppliers	0	22	10	2	0	0.432	21
Cost and man power needed for disposal of the components	0	26	8	0	0	0.4	22

Lack of awareness is the main barrier identified through questionnaire survey with a RII value of 0.811. In Sri Lanka, green roof is a new concept and general public, building owners and developers do not know about green roofs or the benefits they can provide. The second most significant barrier is the lack of space on roof tops with RII value of 0.810. High-rise buildings usually have more problems in promoting green roof as roof space has competing uses including electricity generation (solar/wind/tri-generation), communications towers, helipad, swimming pool and building plants in Sri Lanka and as a result there is no much of a space left to implement green roofs. The third significant barrier is the lack of experienced professionals in Sri Lanka. The compliance with employing green roof system in the existing or new buildings is very low due to the lack of professional experts who can address the complex construction process and technical difficulties within the green roof technologies. Involvement of various professionals is needed for designing, constructing and maintaining the green roofs such as architects or landscape architects, structural engineers, maintenance managers and horticulturalists. Lack of experienced installers is the fourth significant barrier in Sri Lanka for adopting green roof as there are not many green roofing contractors and installers in Sri Lanka. The fifth significant barrier in Sri Lanka for adopting green roof is high construction cost. The initial cost of green roof is higher than a conventional roof due to the professional fees for designing and planning, contractor fees, planning and building permits, demolition or relocation of existing infrastructure on the roof, importing materials and components and addition of specific hard infrastructure elements.

The ways to overcome the barriers were discussed through expert interviews and those ways can be solutions for all the barriers including the most significant barriers. The ways to overcome the barriers were identified as increasing the awareness through encouraging research and development on green roofs, educating and training of professionals on green roof construction and establishing proper government regulation, policies, incentives and promotion. There is a need to increase the level of awareness, knowledge and understanding of green roofs to construction professionals, professionals who are involved in the maintenance and refurbishment of buildings, building owners, developers, stake holders and public. Research on green roofs in Sri Lankan context should be done to give knowledge about green roofs to Sri Lankans. Education programs on green roofs can be organized in order to increase the knowledge and raise the public awareness. Universities and industries should run programs through seminars, presentations, and study tours for high-rise buildings / buildings which have green roofs to raise awareness, support research and trainings.Sri Lankan government should provide tax benefits or an exemption from certain service fees for adopting green technologies including green roofs. Also government can give provision on clean development mechanism and Kyoto protocol. The government can promote green roof technology by giving awards to the buildings or building owners or facilities managers/ chief engineer who have implemented proper green roofs and achieving better energy savings.

5. CONCLUSIONS

There are several negative impacts associated with the urbanization and construction of high rise buildings. Greenery provides several benefits to the environment and reduces the impact of the urbanization. Green roofs are one of the effective strategic to reduce these adverse effects of high rise buildings. In Sri Lanka there are few factors motivating the implementation of green roofs and several factors hindering the adoption of green roofs. This research clearly identified that green roofs are one of the technology which can be applicable in Sri

Lanka and in Sri Lankan high rise buildings. Furthermore the drivers and barriers of green roofs in Sri Lankan context were identified and the ways to overcome those barriers were analysed.

The first five benefits most positively affect the adoption of green roofs in Sri Lankan high rise buildings were found to be: reduction of air pollution, aesthetical appearance, thermal benefits and energy savings, reduction of Urban Heat Island (UHI) effect and points on green rating systems. The first ten barriers that most negatively affect the adoption of green roofs in Sri Lankan high rise buildings were found to be: lack of awareness, lack of space on roof tops, lack of experienced professionals, lack of experienced installers, high construction cost, lack of research on environmental and economic benefits in Sri Lanka, opportunity cost, lack of support from building owners, high amount of maintenance activities and last being lack of government support on policies and regulations. The solutions which were identified are increasing the awareness through encouraging research and development on green roofs, educating and training of professionals on green roof construction and establishing proper government regulation, policies, incentives and promotion, should be established and the green roofs should be included in the upcoming projects for better Sri Lanka.

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APPLICABILITY OF TQM FOR CONSTRUCTION CONTRACTING ORGANISATIONS IN SRI LANKA

W.D.A. Fernando*, L.D. Indunil P. Seneviratne, Mathusha Francis and R. Dilakshan

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

The construction industry in any country is a dominant, huge, complex and highly risky industry. In the Sri Lankan context, the construction industry has become a major component of rapid economic development over the past years. However, the industry itself suffers from many problems, such as defects in workmanship, defects in quality and overflow of time and cost. Thus, these industry problems have challenged the successful project performance and total quality of the output. Nevertheless, these problems will persist until every organization in the industry begins to take responsibility for developing new changes within its own organization. Such changes can be initiated via effectively implementing the philosophy of Total Quality Management (TQM). However, globally, the usage of TQM in the construction industry is not so popular than in the manufacturing industry. Therefore, the research aims to identify the applicability of TQM in Sri Lankan construction contracting organizations.

A qualitative research approach was followed in order to achieve the aim of the study. Thus, semi-structured interviews were conducted among a total of ten top management professionals are associated with contracting organisations and had in-depth knowledge in TQM and its practice. A content analysis using NVivo 11 software was adopted to summarise and analyse the collected data. The findings revealed that TQM can be followed by the construction contracting organizations in Sri Lanka. However, it is not that much easy, because the TQM implementation process encompasses a series of barriers. Thus, the research found financial barrier, insufficient collaborative work, lack of skill, resistant to change, time barrier and less involvement of top management are such barriers in adopting TQM in Sri Lanka. Further the study suggest that barriers must be mitigated cautiously for a better consequence.

Keywords: *Barriers; Solutions; Total Quality Management (TQM).*

1. INTRODUCTION

"Construction industry in any country is a massive, complex and high-risk sector, dominated by contracts" (Gunathilake & Jayasena, 2008). According to Gunathilake and Jayasena (2008) the construction industry has a direct impact on the national economy and is generally used as an indicator of economic well-being of the country. For the past six years in the Sri Lankan context, the construction industry has become a major part of Sri Lanka's rapid economic development and construction organizations are the major representatives of the industry. In the current global competitive environment, the importance of quality has been increased. Nowadays, due to the quality demanding, customers and the massive competition, organizations are more concerned in adopting their own innovative strategies for quality and excellence (Al-Dhaafri et al., 2016). Moreover, the construction industry in many parts of the world suffers from problems such as workmanship defects, quality defects, time, and cost overrun (Harrington et al., 2012). According to Al-Dhaafri et al. (2016) organizations need to implement an advanced management philosophy that can help them to achieve competitive advantages over their rivals for face these problems. Such management philosophy can be initiated through the effective implementations of a Total Quality Management (TQM) philosophy (Harrington et al., 2012). However, TQM in the construction industry is not much popular compared to manufacturing industry. Moreover, Lakhe and Mohanty (1994), stated that there are several obstacles encountered in implementing

*Corresponding Author: E-mail - danasilu.fdo@gmail.com

TQM specially in the developing nations. The anecdotal evidence suggests that the application of TQM is poor in Sri Lankan construction firms. However, according to Bardoel and Sohal (1999) TQM helps to improve better control of processes resulting in consistency from design through to delivery in a construction organization. Therefore, research tends to investigate the applicability of TQM for the Sri Lankan construction contracting organizations.

2. TOTAL QUALITY MANAGEMENT

TQM can be defined as a holistic management philosophy aiming at continuous improvement in all functions of an organization with customer satisfaction to produce and deliver commodities or services in line with customers' needs or requirements with the participation of all employees under the leadership of top management (Demirbag et al., 2006). TQM started to be used in the mid-1980s and became a recognized part of the quality- related world in the late 1980s (Martínez-Lorente et al., 1998). Powell (as sited in Martínez-Lorente et al., 1998) reported that TQM's origins can be traced to 1949, when the Japanese Scientists and Engineers formed a group of engineers and government officials to improve Japanese productivity, and enhance their quality of life after the war. The early evolution of the total quality movement was hardly influenced by few quality pioneers such as Deming, Feigenbaum, Ishikawa, Juran and Crosby (Krüger, 2001). According to Krüger (2001) the contribution of these quality gurus is greatly substantial to today's understanding of TQM. However, most of the quality gurus who have contributed to the improvement of TQM, find their genesis from Deming (Zairi, 2013). The word 'total' in TQM means all functions of the enterprise (Vincent & Joel, 2004). Moreover Besterfield et al., (2005) stated that total stands for "made up of the whole". The second word of TQM is 'quality'. Quality is not a modern concept. Its origins runs towards the ancient history. The concept of Quality has been used through different civilizations for several ages. For example, ancient food collectors had to think about which food is good and which is not good to eat (Elassy, 2015). As for the literature, quality is not a unitary concept. Green (as sited in Elassy, 2015) reported five approaches to define quality. Moreover, quality pioneers such as Deming and Juran explains quality in different manners.

2.1. WHY TQM FOR CONSTRUCTION CONTRACTING ORGANIZATIONS?

However, notwithstanding such kind of quality management systems, still the construction industry is suffering from range of quality problems. According to Battikha (2003) quality related problems can cause penalties, as well as cost and time burdens for rework which directly leads to loss of market share and profit reductions to the construction firm, while it will result in dissatisfaction to the client from problems related to safety, service, and economy. Therefore, a further developed quality management system should be adopted by construction organizations to get rid of these problems. As it has been noted under the quality evolution topic, the last item of the quality evolution graph, TQM can be a solution for the current situation of the construction organizations. Moreover, The construction industry is a heavily characterized, fragmented and freely structured system with the skills, allegiance and direction of various kind of professionals and practitioners (Pheng & Ke-Wei, 1996). According to Pheng and Ke-Wei (1996) the short-term nature of construction projects do not help to create things worthier. Therefore, new methods of procurement are required to overcome the problems caused by the complex nature of construction. The construction industry and the manufacturing industry both are having certain characteristics, such as both focus on product delivery (Lau *et al.,* 2015). Therefore, the TQM philosophy, which was developed in manufacturing industry, can be used in the construction industry as well, and it will beneficial for all the parties in the industry.

TQM is relatively new for the construction industry, but it has made a noticeable influence during the past three decades (Maher-Altayeb & Bashir-Alhasanat, 2014). The principles of TQM helped companies to recover their markets in rival business environments. Therefore according to Maher-Altayeb & Bashir-Alhasanat (2014) construction organizations were encouraged to use the concept of TQM in their market sector. However, the level of usage of TQM principles in the construction industries is vary from country to country (Xiao & Proverbs, 2002). While the US and European construction industries began to develop TQM in the late 1980s, the Japanese construction industry introduced TQM in the 1970s. According to Xiao and Proverbs (2002), the usage level of TQM is relatively lower in developing countries than in developed countries.

2.2. TQM ELEMENTS WHICH ARE NECESSARY FOR CONTRACTING ORGANIZATIONS

Over the past few decades, the quality gurus namely; Deming (in 1986), Juran (in 1986), Crosby (in 1979), Feigenbaum (in 1983) and others have improved and developed certain aspects in quality management and their illustration into quality management provide a better knowledge of quality management principles (Karuppusami & Gandhinathan, 2006). However, the same basic drawback has been shared by all of them, that how to manage quality to gain a competitive advantage through a greater customer satisfaction and with a better performance (Aquilani *et al.,* 2017). According to Aquilani *et al.* (2017) in addition for this customer satisfaction, in new business environments such as value co-creation, the importance of quality management is recognized to be dominant. Therefore rather than disposing those traditional quality management principles they must simply be reinterpreted with major elements to ensure the quality of fulfilled experiences. However, according to Salaheldin (2009) the first step before implementing of TQM in any background is to identify its most important and substantial points. There were several studies that have been undertaken on identification of these points, commonly referred to as major elements and also critical success factors (CSFs) (Mehralian *et al.,* 2016). According to Aquilani *et al.* (2017) these elements may be viewed as variables that determine organization's performance through successful execution of TQM. The elements can be defined as the critical areas which organization must implement to achieve its mission by examination and categorization of their impacts (Oakland & Aldridge, 1995). According to Kumar *et al.,* (2011), major elements of TQM are leadership and top management commitment, customer satisfaction, continuous improvement, teamwork, employee training, and effective communication.

2.3. TQM TECHNIQUES AND TOOLS WHICH ARE NECESSARY TO CONTRACTING ORGANIZATIONS

Other than TQM elements, TQM tools are another important aspect regarding TQM. According to Hellsten and Klefsjö (2000) a TQM tool have a statistical basis to support, facilitate analysis data and for decision making. The three components, which are elements, techniques and tools, are interdependent on each other and support each other for success of the TQM. As for example, the element of customer satisfaction cannot be implemented without a suitable technique. One of technique might be quality circle. However, this technique will not work effectively and efficiently without the use of specific tools such as Pareto diagram, histograms. Even more, tools and techniques are practical methods, skills or mechanisms that can be applied to particular tasks and can be used to ease clear changes and improvements (McQuater *et al.,* 1995). Arditi and Gunaydin (1997) stated that for a better feedback which is a major element of TQM, these quality tools are essential. Besides, teams with these tools can identify the causes of quality problems and can verify, repeat, or reproduce measurements based on data, to determine the future status of a work process by examine the past and present, and to make decisions on facts that are based on data rather than the opinions of individuals or other groups (Arditi & Gunaydin, 1997). Namely, cause and effect diagrams, Pareto analysis, control charts and flowcharts can be identified as quality tools which are important to construction organizations. On the other hand, 5S practice is one of the most important technique that will provide base for the implementation of TQM for an any kind of organization. Table 1 will provide basic definitions on such kind of TQM tools.

Table 1: TQM Tools

Tool	Definition
Cause and effect diagram	A schematic tool that resembles a fishbone that lists causes and sub-causes as they relate to a concern, also known as Fishbone diagram or Ishikawa diagram
Check sheet	A form used to collect, organize, and categorize data so it can be easily used for further analysis
Histogram	A graphic display of the number of times a value occurs
Pareto diagram	A bar chart that organizes the data from largest to smallest to direct attention on the important items (usually the biggest contributors)
Process flow diagram	A graphical illustration of the actual process
Scatter diagram	A graphical tool that plots one characteristic against another to understand the relationship between the two
SPC control chart	A graph of time-ordered data that predicts how a process should behave

Source : (Hagemeyer *et al.,* 2006)

3. METHODOLOGY

The research focuses on feelings, attitudes and beliefs of a group of people, about the applicability of TQM for the Sri Lankan construction firms. The research problem is 'what are the barriers in implementing TQM in contracting organizations?'. Thus, the research problem is subjective. The results have to be presented in a subjective manner. It seeks to explore and understand a phenomenon such as "what?" amd "why?" rather not trying to confirm a hypothesis about phenomena such as "how many". Therefore, this research has been conducted according to the qualitative approach. However, there are several methods to collect data in a qualitative research such as interviews, focus group discussions, photo voice and picture story. Among those, semi structured interview is the suitable method because it will provide primary data in such a way to gather information to a greater depth in a low rate of non-response with the control of sample more effectively. However, Kothari (2004) stated that this kind of method remains the possibility of the bias of respondent. Therefore, selected professionals were interviewed in a way that bias could not occur.

In content analysis, which is a qualitative data analysis method, start with some ideas about the hypotheses, or issues that may arise, and look for them in the data which has been collected. But in other methods, such as statistical data analysis methods looks only for the collected data, not interested in literature (Schutt & Chambliss, 2013). Therefore, the content analysis, which is a research technique based on systematic text description has been used as the data analysis method for this research. A Qualitative research basically focuses on a limited number of respondents (Rajasekar *et al.,* 2006). They will be selected purposefully, with the belief that they have in-depth knowledge of the issue discussing in the research problem. For the current research, snowball sampling was selected. Because it helps to ask from others to identify people who have in-depth understanding about TQM. However, qualitative research generally does not involve the use of a fixed sample size. (Robert, 2011). According to Robert (2011) saturation is a tool that is used to ensure that adequate and quality data are collected to support the study. When the variation of data is degraded, when new perspectives and explanations from data are no longer coming in, saturation point may be approached. According to Kothari *et al.* (2014) saturation point can occur after 12 or most of the cases after 6 interviews. However, while doing ten semi-structured interviews, saturation level reached. Therefore, total number of semi-structured interviews was limited to ten. The profile of interview participants as follows.

Table 2: Profile of Interviewees

Interviewee	Designation	CIDA grade of the organization	Industry experience
R1	Acting Head of QA Division	C1	17 Years
R2	Project Manager	CS2	20 Years
R3	Contracts Manager	CS2	10+ years
R4	Manager Projects	CS2	21 Years
R5	Assistant General Manger	CS2	20 Years
R6	Chief Structural Engineer	CS2	15 years
R7	Project Manager	CS2	14 Years
R8	Senior Project Manager	CS2	14 Years
R9	Contract Manager	CS2	11 Years
R10	Senior Project Manager	C1	11 Years

4. DATA ANALYSIS AND RESEARCH FINDINGS

4.1. CURRENT QUALITY MANAGEMENT PRACTICES IN CONTRACTING ORGANIZATIONS

As per research findings, many of the organizations having ISO 9001 quality policy, which is a quality assurance procedure, coming on the way to TQM. However, just having a quality assurance is not enough for TQM. Because just having an ISO certificate will not ensure that particular organization has adopted TQM. Until getting a quality award such as Deming prize, Malcolm Baldrige National Award or European Quality Award, any organization could not mention that they have been awarded as a TQM adopted organization. However, having such quality assurance in hand is a useful thing when going towards TQM.

Leadership and top management commitment is one of the major element in TQM. However, according to the findings, the current level of commitment that top management shows towards the quality is in a satisfactory level or more because the top management commitment towards quality is a major key factor in determining TQM success. Moreover, the top managers are consistently participating in activities to improve the quality of the organization is also agreed by all the respondents which means in each and every project the top managers participate in quality related problems and take necessary actions to improve the quality of the organization. Moreover, the organizations which have a formal mechanism system to recognize its employees through suggestion scheme or improvement of ideas are very few. All the employees must be recognized through a suggestion scheme. Their improvement of ideas should be evaluated and recognized. Conducting this kind of employee recognizing procedure is top managers' responsibility. However, all the respondents who mentioned that they have an employee recognizing mechanism, is limited to several kinds of employees. Not for all the employees in the organization. Therefore, it is not enough for an organization who are trying to adopt TQM.

Customer satisfaction is another most important element in TQM. Because the quality is based on customer's expectations. TQM is about one hundred percent customer satisfaction. Most of the respondents mentioned that, even they do customer satisfaction surveys it is limited from beginning of the project until the end of defect liability period. However, having a customer satisfaction of that level is not enough for TQM. Organizations should carry out the customer satisfaction surveys even after the end of the defect liability period. That is the way to get customer satisfaction which has been mentioned in TQM. Because as for literature findings, during the consumption and after the consumption of a product or service, customers will develop positive feelings of satisfaction or negative feelings of dissatisfaction. Furthermore, none of the respondents mentioned that he or she disagrees with the organizations assessing of future customer needs and expectations. However, none of them mentioned that they strongly agree with it. Because of the ISO requirement, they only do the complaint handling procedures and seek customer views.

Continuous improvement is an ongoing process which is helpful to develop an organization's quality environment. Learning through mistakes, procedures are most important in continuous improvement. However, within these contracting organizations learning through mistakes procedures are not practicing that much well. Because continuous improvement talking in TQM does not allow for repeat the same mistake again. However, according to the research findings the same mistake is happening again within these organizations. Continuous improvement talking in TQM does not allow for repeat the same mistake again. Continuous improvement is a step-by-step process. As for the literature findings the PDCA (Plan-Do-Check-Act) cycle is the best tool to use in continuous improvement process. However, most of the respondents mentioned that they even do not know about it.

Employee training is another element in TQM, which helps employees to gain particular knowledge and skills to improve their performance. However, training identified in TQM is not that simple, as per literature findings each and every level of employee should be trained to get a better performance to the organization. Without this requirement, TQM could not be achieved. In these contracting organizations this procedure is not happening. All the respondents mentioned that their organizations have various kinds of training programs for employees. But when the question raised whether each and every level of employee is being trained, the answer was 'no'. Additionally no single organization conducts training programs regarding TQM for their employees according to the respondents. Therefore, contracting organizations should think about TQM training for their employees. However, it is important to conduct TQM training for top level managers first, before providing it to lower level employees.

The fifth TQM element which has been investigated in this research was 'Teamwork'. Any construction project is a team effort. However, that team should be purposeful and effective. Further, these teams are not only the project teams, which consists of designers, subcontractors, suppliers and customers. There can be other several number of teams within the organization. For example, quality circles can be within the organization to develop quality procedures within the organization. However all the respondents mentioned that they have a successful teamwork approach in place, when undertaking any project. It is a good sign for TQM adaptation.

Effective communication is yet another major element of TQM. However, the respondents mentioned that there are several communication tools which are being used within their organizations to communicate with each other. However, all the respondents mentioned that they are using progress review meetings as a communication tool. Moreover, emails are also used as an effective communication tool. Only a little number of organizations are using organization magazines and quarterly newsletters as communication tools.

Therefore, they have to develop communication system within their organizations by using these kind of communication tools.

Moreover, the usage of quality tools is at a very low level within these contracting organizations. As for example, Pareto diagrams are a major tool that can be used in contracting organizations. The purpose of the Pareto chart is to identify the most important elements among a typically large set of factors. In quality control, it often illustrates the most common sources of defects or the most frequent reasons for customer complaints, and so on. However, no any single organization, which has been selected to the research, is using Pareto diagrams. Therefore, these kind of quality management procedures will not help to develop TQM within these contracting organizations. Table 3 illustrates the usage of quality tools within their organizations. According to below table check sheets, process flow diagrams and histograms are the mostly used quality tools in these contracting organizations. However, PDCA cycles, SPC charts, Pareto diagrams and 5Why analysis are not that much popular within these organizations. However, those quality tools are required for quality related matters within organizations. Without using these tools, these organizations are going away from their total quality concept. Moreover, PDCA is a very effective tool or sometimes act as a TQM technique in the continuous improvement process.

Table 3: Usage of Quality Tools

Quality tool	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
Cause and effect diagrams	✓	✓			✓	✓				
Check sheets	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Histogram		✓		✓		✓		✓	✓	✓
Pareto diagrams										
PDCA cycle	✓				✓					
Scatter diagrams	✓					✓				
SPC charts					✓					✓
Process flow diagrams	✓	✓	✓		✓	✓	✓	✓	✓	
5Why	✓									

However only two respondents mentioned that their organizations are using PDCA cycle as a technique for the continuous improvement process. Another important tool is 5Why analysis. It directs the analyser for the root cause of a problem after asking the question 'why' serval times. Obviously, the reason for this is the lack of knowledge regarding this kind of quality tools. As an illustration respondent R3 mentioned, *"I don't know much about those tools; therefore I can't give a valid explanation".* Especially when the top-level managers do not have a knowledge about these tools, then how the other people would know. Because TQM is a philosophy, which is addressed total. Even the labour at a site should be able to analyze a problem using 5Why. Most of the respondents stated that their knowledge about this kind of quality tools is poor. In addition, one mentioned that lack of experience regarding these tools is also a barrier for usage of quality tools. Even though they have the knowledge, it is not enough. There should be an environment to use these tools within the organization.

4.2. BARRIERS TO IMPLEMENT TQM IN CONTRACTING ORGANIZATIONS

According to the study, several barriers were identified for the proper implementation of leadership and the top management commitment under Sri Lankan context. Most of the respondents mentioned about the financial barrier. Because of the low finance availability, they could not conduct employee suggestion scheme for each and every employee. Moreover, some respondents stated that the lack of skills and knowledge about the quality concept are also barriers to an excellent top management commitment with regard to quality improvement of the organization. In addition, time barrier, resistance to change for a quality environment and insufficient collaborative work also came out as barriers for a proper top management commitment towards the quality, within the organization. Figure 1 illustrates the identified barriers using NVivo 11 software.

Name	Sources	References
Barriers for Leadership and top management commitment	0	0
Financial barrier	5	5
Insufficient collaborative work	1	1
Lack of skill	3	3
Resistant to change	2	2
Lack of knowledge	3	3
Time barrier	1	1
Top managers direct involvement is less	2	2

Figure 1: Identified Barriers for Top Management Commitment

Without the customer satisfaction any organization cannot achieve TQM. However, the research identified several barriers under customer satisfaction. Almost all of the respondents mentioned financial barrier as a huge problem. Doing a customer satisfaction survey is very costly as for their opinions. However, some of them stated about that insufficient time is also a massive problem to do such kind of surveys even before the defect liability period. In addition, one respondent mentioned that if the level of relationship with the customer was at a minimum level then it would be a problem for having a better customer satisfaction. Because having a good direct relationship with the customer is always better. Moreover, changing customer needs from time-to-time was also mentioned as a barrier to a proper customer satisfaction.

Continuous improvement can be achieved through having quality circles within the organization. Almost all of the respondents mentioned about the financial barrier. To adopt continuous improvement procedures, there should be sufficient budget allocation for that. Even in government sector or private sector the financial problem is everywhere. Having insufficient finance allocation they could not conduct additional continuous improvement programs. Secondly most mentioned barrier was carelessness of the employees and the lack of employee involvement. Even the main point of continuous improvement, which is learning through mistakes, they could not do accurately because of employees' carelessness. In addition, the involvement of the employees is also at a low level for this kind of quality improvement procedures. Three respondents mentioned that time is also a big problem because time is a limited thing. Without having time, nothing be done. In addition to these barriers, over workload, lack of competent managers to handle continuous improvement process and insufficient communication system within the organization were also identified as barriers for continuous improvement in the organizations.

Employee training is another element of TQM. Almost all the respondents identify financial barrier is a critical problem to these kind of training programs. Moreover, insufficient time also came out as a barrier from most of the respondents. Other than that the high employee grievances popped as a barrier for training programs. Since the current procedure is giving training for limited number of employees who were selected, others' grievances are getting high. Moreover, due to poor performance of the above employee selection procedure, unsuitable employees are being selected rather selecting suitable employees. In addition to those barriers, some other several barriers also came out such as negative view of the top managers regarding conducting training programs for employees, employees' lack of commitment for training programs and useless employee problem. While some employees are rising grievances about their non-selection, on the other hand some are giving very low commitment for such kind of training programs. Therefore, these mentalities must be totally removed for a TQM adoption. The respondent R6 mentioned, "*Even if we give training for everyone, there are some employees who couldn't learn something and they are incapable*". Therefore, this kind of employees, is a problem to the organization.

Teamwork is another element in TQM. However, several barriers were identified for the proper implementation of teamwork in the industry. Different personal attitudes in different people is one of the most significant barrier identified by many respondents. Because team should walk in a common path to a common goal. Because of these different attitudes, it will become more difficult. Respondent R3 gave his opinion like this. "*It depends on personal behavior. In a country like Sri Lanka, we can't go for team work and take a win-win scenario. Our people are not accepting that. Always try to argue with each other. Try to fight each other. For example, when a dispute arisen, every party tries to convey their opinion is right, and other one is wrong. Having this kind of attitude, we can't derive the actual benefit from team work*". In addition, lack of collaborative work also came out as a barrier for teamwork among several respondents. Another barrier identified was the carelessness of the employees. When working as a team all the team members work with an effective manner. Without being careless. Other than these barriers there were some other barriers which were identified. Occurrence of the idle time, reducing the decision making process and lack of taking responsibility are those. Respondent R9 stated, "*Sometimes they just pass the time because some work should be completed, before starting their work. Until then they are just waiting. I think these are coming from our culture*". Nevertheless, because of the teamwork concept, some people do not take responsibility. Respondent R7 highlighted, "*Some employees try to shirk their responsibility because of the team work. They think that "it is not my job, it is up to us" and give the whole work to others"*. Accordingly, there are several barriers to adopt purposeful teamwork with an organization.

Effective communication is the last element of TQM which has been discussed in this research. However, there were several barriers identified for the effective communication. Almost all the respondents mentioned about the language barrier. In an organization, there are people who are working in different nationalities and in different culture. For an effective communication, this is a major barrier as for their point of view. Another identified major barrier is the carelessness of the employees. As per respondent R6, "*Also carelessness is there. Sometimes the message doesn't reach the targeted people. It stuck in the middle because of carelessness"*. This kind of mistakes should not occur in an organization who are looking for adopting TQM. Furthermore, the lack of management commitment is also identified as a barrier for effective communication. Management commitment should be everywhere. Because the leadership and the top management commitment is one of the major element of TQM which was discussed above*"*. Moreover, lack of attention is also identified as a barrier for an effective communication system. Respondent R3 stated*, "Also the listening skill should be there, some people do not have the patience to listen. Sometimes in meetings, a particular thing is being said a lot of times. But finally they got it in a different manner"*. Therefore, this kind of bad qualities should be avoided when walking towards TQM. Other than these barriers, some other barriers were identified by a few respondents. They are lack of relationship between employees, insufficient communication skills and the cultural barriers. Respondent R4 highlighted, "*Also in some organizations the bottom level employees haven't any chance to reach top level managers. So this can also be a communication barrier. Because the relationship between the employees are not that good. Therefore, communication doesn't work well"*. Therefore, this also occurs because of the leadership and the top management commitment is not in a good position in those organizations.

Moreover, there were several barriers identified for the usage of TQM tools and techniques also within these organizations. Resistance to change, insufficient time, lack of knowledge about those tools, unavailability of funds and finally the carelessness of the employees are those barriers. Resistance to change is one of the major barrier, which was identified by most of the respondents. Respondent R2 mentioned, "*The main difficulty is the resistance to change. Employees already like to maintain the practices, which are being used for a long time. Because of that it's difficult to adopt new practices at once"*. Moreover, financial barrier represents on this matter also. Hence a developing country this financial barrier is a common situation which has been faced by all the industries within the country. Moreover, the respondent R2 illustrates another major barrier that reduce the TQM adoption in contracting organization. According to respondent R2, the unstable labour force is a critical situation that the industry faces in present. Without having a stable labour force, TQM could not be possible. Furthermore, the respondent R4 stated that adopting TQM within contracting organizations is not enough. According to respondent R4's opinion, all the parties who involve in a construction project should adopt TQM to get the best outcome from TQM implementation.

4.3. SOLUTIONS FOR THE BARRIERS

According to the opinion of the respondents and the literature findings, there were many barriers against adopting TQM. One major barrier is the financial unavailability. Almost all of the TQM elements discussed above were suffering because of the financial unavailability within these organizations. Therefore, they have not any chance to develop their quality management systems for a better status. However, as a developing country, these organizations could not grant that much of finance for quality improvement procedures. Identify the main problem that causing the financial difficulties, get the financial support from banks and identify new ways which generate income are the solutions for the financial barrier. For an example contracting organizations can become developers to generate additional income. Prepare time tables, change the attitudes of the employees, allocate the work load effectively and conducting training programs are some of the solutions for the time barrier.

Employees' resistance to change can be overcome through identifying the root cause of resistance and prepare necessary plans to address the root cause. The best way to identify the root cause of resistance is through a personal conversation between a resistant employee and their supervisor, which leads to the final tip for managing resistance. With the knowledge of primary root causes, change management teams can adequately prepare an exciting case for the need for change, which is communicated by senior leaders in the organization. Moreover, communicate the change effectively, implement change in several stages and engage top managers as active and visible sponsors of change are some other solutions for the resistance to change barrier. Lack of skill and knowledge is another major barrier in TQM adaptation. However allocate more funds on training programs, implement pre-defined recruitment process and performance evaluation can be recognized as solutions for this barrier.

Besides, the communication barrier can be mitigated through selecting leaders who are having great communication skills, encourage team work, training on communication tactics and organizing extra-curricular activities within the organization. Another industry specific barrier for TQM is unstable labour force. Interview applicants carefully, introduce flexible work structure, pay attention to employees' personal needs and create the path to career growth are some of the solutions for the unstable labour force problem. It cannot be practicable for apply all these solutions at once within an organization. However, it also not be impossible to initiate these solutions in step by step as a continuous improvement procedure.

5. Conclusions and Recommendations

This paper signifies the applicability of TQM for Sri Lankan contracting organizations. However, according to the research findings, the present quality management procedures within contracting organizations are not at a very much satisfactory level. When talking about total quality, that procedure is not even at satisfactory level. However, several barriers were identified as major difficulties to adopt TQM in contracting organizations. Insufficient budget allocation and insufficient knowledge about TQM are the most critical barriers. Moreover, the total concept is not practicable sometimes, due to several characteristics in the construction industry. Construction project is consists with several parties such as main contractor, designers, subcontractors, suppliers etc. However, adopting TQM only for main contracting organization is not enough for the perfect quality of the output. All the parties, which were mentioned above, should be adopted TQM within their organizations. Otherwise, the best performance of TQM could not be achieved through the final output.

Nevertheless, the labour problem within the industry is also a significant barrier for the TQM adoption. In Toyota, which is an organization adopting TQM in present, they have stable labour force. However, in Sri Lankan construction industry the labour force is not stable. Even if a labour was well trained for TQM, but what is the point of giving him a such kind of training, if he left the organization two or three weeks later. Therefore, these kind of characteristics within the industry is also reduce the adoption of TQM within contracting organizations. However, when considering benefits of TQM for the construction industry as mentioned above it is give an acceleration for TQM adoption. However, as per the research findings, TQM is applicable for contracting organizations in Sri Lanka. First, the current malpractices within the industry such as labour problem should be avoided. Subsequently, a proper knowledge regarding TQM should be provided. Ultimately, allocating sufficient money and time will supply the foundation to TQM within contracting organizations. After that, other parties who involved in a construction project can also adopt TQM for a most perfect quality output.

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ASSESSMENT OF GREEN RETROFIT OF EXISTING MATURE RESIDENTIAL ESTATES IN SINGAPORE

Bon-Gang Hwang, Ming Shan* and Sijia Xie

Department of Building, National University of Singapore, 4 Architecture Drive, Singapore

ABSTRACT

While the authorities in many countries around the world launched green retrofit programs to upgrade the existing mature buildings during the past decade, limited was known about the residents' perceptions of those programs. As a result, this study aimed to investigate the residents' perceptions of the green retrofit programs in Singapore, which is one of the leading countries for green development, and to explore their willingness in extending green retrofit into their individual houses. A questionnaire was administered to 90 residents from a mature public residential estate in Singapore that just underwent a pilot green retrofit program. The results reported that 86 percent of the respondents were satisfied with the green retrofit program, and their most favourite green feature installed was the outdoor light emitting diode lighting. In addition, over 50 percent of the respondents were supportive of having their individual houses undergo green retrofit and were willing to bear an upfront cost up to SGD 5,000 (approximately USD 3,540). This study also found that achieving cost savings from lower utility bills in the long run was the top motivation that drives the residents to retrofit their houses. This study contributes to the body of knowledge by conducting a thorough investigation of residents' perceptions of green retrofit programs. Furthermore, the findings from this study provide the industry and the authorities running green retrofit programs with the opportunities to reveal respondents' preferences on different green features, and to upgrade their green retrofit programs accordingly, creating more sustainable benefits for the residents.

Keywords: *Green Retrofit; Questionnaire; Respondents' Perceptions; Singapore.*

1. INTRODUCTION

As defined by the Organization for Economic Co-operation and Development (OECD, 2002), residential buildings are a particular type of built environment that is constructed to satisfy peoples' dwelling needs. However, residential buildings have also been criticized as a major consumer for energy and a significant contributor to waste (Shen et al., 2016). According to Santamouris et al. (2007), residential buildings consumed 20 percent of the energy in OECD countries. Balaras et al. (2007) stated that residential buildings accounted for 63 percent of energy consumption and 77 percent of CO_2 emission in the building sectors of European Union member countries. Therefore, the authorities worldwide have launched a series of initiatives aiming to reduce the resource consumption and achieve a better energy efficiency in residential buildings (Liang et al., 2016). It is noteworthy that these initiatives not only emphasized the development of new eco-communities but also stressed the green retrofit in existing mature residential estates (Zuo and Zhao, 2014).

In a typical densely populated metropolis like Singapore, a large number of residential buildings have been built to address people's housing needs (Agarwal et al., 2016). According to the Housing and Development Board (HDB, 2016b), more than 88 percent of the existing residential buildings in Singapore were built before 2005, the first year when Singapore launched its green building campaign (BCA, 2014). This ratio implies that there will be considerable residential buildings facing green retrofit in the future. In 2012, the Singapore government launched a green retrofit program named HDB Greenprint in several existing mature residential estates, aiming to improve their energy efficiencies and provide their residents with a healthier indoor environment (HDB, 2016a). Although there have been considerable studies relating to green retrofit in the

*Corresponding Author: E-mail – bdgsm@nus.edu.sg

current literature, most of them concentrate mainly on the environmental benefits generated from the retrofitting (Liang et al., 2015, Wilkinson et al., 2015). Very few have investigated the residents' perceptions of the green retrofit programs. As a result, this study aims to bridge the knowledge gap. Among those pilot estates in Singapore, Yuhua is the first mature residential estate to undergo the green retrofit and its retrofit work already completed in November 2015. Thus, the objectives of this study are to investigate the residents' perceptions of the pilot green retrofit program, explore their willingness to expand the green retrofit program in their individual houses, and propose some practical recommendations to enhance the existing green retrofit program in Singapore.

This study contributes to the current body of knowledge by adding the literature of green retrofit. Furthermore, this study benefits the practice as well, because the achievements and lessons learned from the current practices were carefully summarized, which can be used to improve and upgrade the existing green retrofit programs effectively in the future.

2. BACKGROUND

2.1. GREEN RETROFIT

The existing research on green retrofit is mainly concentrated on three areas: benefits of, decision-making of, and implementation of green retrofits. For example, Wilkinson and Reed (2009) illustrated the benefits and potential for green roof retrofit to commercial buildings in a city centre to property managers and other property professionals. Berardi (2016) investigated the benefits on the local microclimate and the building energy saving resulting from green roof retrofits. Castiglia Feitosa and Wilkinson (2018) assessed the benefits of green wall retrofit in attenuating the urban heat island effect and internal temperatures in buildings. In addition to the benefits of green retrofit, decision-making of green retrofit also attracts attention from the researchers. For instance, Booth and Choudhary (2013) analysed how decisions can be made in the face of the uncertainties involved in the retrofit analysis of a housing stock. Liang et al. (2016) analysed the behaviours of the building owners and occupiers, who are the direct decision makers in initiating green retrofit at the initial intention phase, using game theory. Fan and Xia (2018) presented an optimization model that can help decision makers to identify the best combination of green retrofit options. Furthermore, many studies look into the implementation of green retrofit. Jin et al. (2014) explored the operation modes of the green retrofit supply chain. Hwang et al. (2015) addressed the risks in green retrofit projects and came up with a comprehensive set of mitigation strategies that can tackle those risks. Liang et al. (2015) examined the critical success factors for the implementation of green retrofit from a stakeholder perspective, using the approach of social network analysis. Bu et al. (2015) conducted a literature review of the existing building retrofitting process, especially examined the functional, technical and organizational issues of the green retrofit process. According to the literature review presented above, it can be observed that the existing research on green retrofit is abundant; but very little of them has investigated people's perceptions of green retrofit.

2.2. PUBLIC HOUSING IN SINGAPORE AND THE GREEN RETROFIT EFFORTS

Singapore is a small and compact island but with a large population, making public housing a critical issue to the local authority and society (Phang, 2015). In order to tackle this knotty problem, Singapore government established the Housing Development Board (HDB) in 1960, an authority entrusted with the responsibility of providing quality homes and living environments for Singapore people (Low et al., 2012). Over the past five decades, HDB has built 1,116,485 subsidized flats across the island for the 3,408,900 Singapore citizens (HDB, 2016b). Currently, 80.2 percent of Singapore's population are living in HDB flats and 90.8 percent of them own their flats (Department of Statistics, 2016). The high lodging and home ownership rates have suggested that the public housing system of HDB achieved unprecedented success in Singapore.

As a world class leader in the area of green buildings, Singapore has also intensified its green efforts in the sector of residential buildings. Particularly, the local authorities like BCA and HDB have launched a series of initiatives to retrofit those existing traditional residential buildings, considering that the majority of them are the traditional ones that were designed and built previously without sustainable considerations (HDB, 2016a). For instance, in 2011 the BCA launched the BCA Green Mark for Existing Residential Buildings, aiming to help the building owners and facility operators carry out green retrofits from the perspectives of energy efficiency, water efficiency, sustainable operation and management, and community and well-being (BCA, 2011). In 2012, HDB launched the HDB Greenprint scheme and piloted it in Yuhua Estate firstly (HDB, 2016a). More details of the green retrofit program at Yuhua Estate are introduced in the following section.

2.3. THE HDB GREENPRINT @ YUHUA ESTATE

The green retrofit of Yuhua Estate was coded as HDB Greenprint@Yuhua, and it was carried out between October 2012 and November 2015, costing SGD 23 million (approximately USD 16.6 million) (HDB, 2016a). The retrofit involved 38 blocks and affected 3194 households living in this community. Five specific green features, namely elevator energy regeneration systems, solar photo voltaic systems, outdoor light emitting diode (LED) street lighting, rainwater harvesting systems, and pneumatic waste conveyance systems, were installed under this retrofit program. Among these green features, the elevator energy regeneration system is an innovative type of elevator that can save power consumption by reusing the energy recovered from the elevator's descending travels with heavy loads and ascending travels with light loads. The solar photo voltaic system is installed to convert the natural sunlight into solar power that can be used to power lift and light common areas like corridors and staircases. The rainwater harvesting system is designed to collect rainwater for common area washing and landscape irrigation. The pneumatic waste conveyance system is an automated and enclosed waste collection system which uses high-speed air suction to transport household waste via an underground pipe network to the centralized bin centre. The outdoor LED street lighting refers to the replacement of conventional bulbs for the LED bulbs in the car parks and driveways to the car parks, which can not only reduce energy consumption but also increase residents' safety as parking areas and driveways are now brighter due to higher lumens. Moreover, to encourage the use of energy-efficient appliances in homes, the HDB Greenprint@Yuhua also introduced Green Home Package and offered the residents of Yuhua discount coupons (10 to 30 percent off) for their purchases of electrical appliances like refrigerators, air-conditioners, LED televisions, washing machines, lightning and fans.

3. METHODS AND DATA PRESENTATION

As a systematic method of collecting data based on a sample, questionnaire is widely used to gather professional views in sustainable construction research (Hwang et al., 2015). Thus, this study decided to administer a questionnaire to investigate the residents' perceptions of the HDB Greenprint @Yuhua.

The developed questionnaire was structured into three sections. The first section sought respondents' background information, including the types of their flat, the size of their households, their monthly household income, and their monthly household utility expenditure. The second section of the questionnaire solicited respondents' overall satisfactions with the HDB Greenprint@Yuhua, as well as their perceptions of the five essential components of HDB Greenprint@Yuhua. The third section of the questionnaire solicited respondents' willingness and considerations of extending the green retrofit program into their individual houses. This section also sought the green features that the respondents would like to install most in their individual houses. A five-point scale was employed as the rating system in the second and third section. Furthermore, to ensure the readability, comprehensiveness, and accuracy of the questionnaire, pilot surveys were conducted with two HDB engineers that were involved in HDB Greenprint@Yuhua. Based on their comments, slight revisions were made to the statements in the questionnaire, and footnotes were added to explain the terminologies used. Table 1 shows the framework of the questionnaire.

Table 1: The Framework of the Questionnaire

Questionnaire scope	Code	Item surveyed by the questionnaire
Satisfaction with the HDB Greenprint@Yuhua	A	Overall satisfaction
	B1	Greenprint program: solar photovoltaic system
	B2	Greenprint program: elevator energy regeneration system
	B3	Greenprint program: outdoor LED lights
	B4	Greenprint program: pneumatic waste conveyance system
	B5	Greenprint program: rain harvesting system
	C	Endorsement on the generalization of the HDB Greenprint program

Questionnaire scope	Code	Item surveyed by the questionnaire
Willingness to extend green retrofit into individual houses	D	Willingness to pay for retrofit
	E	The scale of the upfront cost would bear
	F1	Consideration: pride of owning
	F2	Consideration: cost saving
	F3	Consideration: better aesthetic
	F4	Consideration: higher resale value
	F5	Consideration: attractiveness for rental
	F6	Consideration: financial assistance
	F7	Consideration: saving environment
	G1	Green feature: energy monitoring system
	G2	Green feature: low e-film window
	G3	Green feature: LED lighting
	G4	Green feature: dimmer switch
	G5	Green feature: low-flow water

To disseminate the questionnaire, an online survey was created first. Then, a letter of intent was prepared, which explained the purposes and objectives of the survey and included the link to the questionnaire. Then, the letter of intent was delivered to the mailboxes of 385 households which were proportionally selected from the entire Yuhua Estate community. The 385 households selected were offered a period of six weeks to respond, and a door-to-door reminder was sent to obtain more feedback. Finally, a total of 100 responses were received, and ten of them were eliminated due to its low degree of completeness. Thus, the number of the valid responses was 90, representing a response rate of 23 percent, which was consistent with the norm of 20 to 30 percent with the most questionnaire surveys in the construction management research (Akintoye, 2000). Table 2 presents the profile of these 90 households.

Table 2: Profiles of the Respondents

Profile	Frequency	Percentage	Cumulative Percentage
Type of flat			
1- & 2- room flat	5	5	5
3-room flat	25	28	33
4-room flat	33	37	70
5-room & Executive flat	27	30	100
Size of household			
1-2 people	5	6	6
3-4 people	31	34	40
5-6 people	53	59	99
7 people or more	1	1	100
Monthly income of household			
Less than SGD 2K	6	6	6
SGD 2K - SGD 4K	17	19	25
SGD 4K - SGD 6K	32	36	61
SGD 6K - SGD 8K	24	27	88
SGD 8K - SGD 10K	9	10	98
Above SGD 10K	2	2	100
Household monthly utility bill			
Less than SGD 50	4	4	4
SGD 51 - SGD 100	36	40	44
SGD 101 - SGD 150	39	44	88
SGD 151 - SGD 200	9	10	98
Above SGD 201	2	2	100

Statistical tests were conducted to analyse the collected data. As many statistical tests require the normal distribution of the data (Kim, 2015), the data normality test was conducted first. Upon the recommendation of Gel et al. (2007), the commonly used Shapiro-Wilk test was conducted to check the normality, with the aid of SPSS Statistics 17.0. Considering the respondents for the questionnaire are households from different groups in terms of flat type, the size of household, household monthly income, and household monthly utility expenditure, it is necessary to conduct an inter-group comparison. Two widely used inter-group comparison tools, namely Kruskal-Wallis test and one-way analysis of variance, were considered. Kruskal-Wallis test is a non-parametric statistical test method suitable for processing non-normal data, while one-way analysis of variance is a parametric statistical test method suitable for processing normal data (Shan et al., 2017). Therefore, the results of the Shapiro-Wilk test determine which inter-group comparison tool shall be used for this study.

4. RESULTS AND DISCUSSIONS

Table 3 presented the results of data analysis. According to the results of Shapiro-Wilk test, the collected data were not normally distributed. Therefore, the Kruskal-Wallis test was used to conduct inter-group comparison.

4.1. RESIDENTS' PERCEPTIONS OF THE COMPLETED HDB GREENPRINT@YUHUA

4.1.1. RESIDENTS' SATISFACTIONS WITH HDB GREENPRINT@YUHUA

According to Table 3, the respondents' overall satisfactions with HDB Greenprint@Yuhua scored 4.10, suggesting the residents of Yuhua Estate were largely satisfied with the program. Table 3 also showed the five specific green features of this program received satisfaction assessments from 3.73 to 4.05, indicating all of them have satisfied the residents. The outdoor LED lighting obtained the highest assessment of 4.05 and was the most satisfied green feature, followed by pneumatic waste conveyance systems (4.01), rainwater harvesting systems (4.01), solar photo voltaic systems (3.95), and elevator energy regeneration systems (3.73).

Despite the unanimous satisfactions, differences were found among the households, particularly in terms of their monthly household income and monthly household utility expenditure. The Kruskal-Wallis test results in Table 3 showed that the households receiving monthly incomes less than SGD 2K (USD 1.4K) and above SGD 10K (USD 7.2K) gave relatively lower assessments than the rest households. In Singapore, the families who received monthly incomes less than SGD 2K were low-income families. Individuals from these families are normally pessimistic about their lives owing to their limited income, and this might be the reason why they gave relatively low assessments to the HDB Greenprint@Yuhua. Conversely, the families whose monthly incomes exceed SGD 10K are high-income families in Singapore. Individuals from these families always have high standards and expectations for their lives, and this might be the reason why they gave low assessments. Furthermore, Table 3 showed that the households paying a high monthly utility bill (i.e., above SGD 201) gave significantly lower assessments of satisfaction than the rest households. This might be because these families normally use considerable household appliances and the savings generated by the installed green features are limited which cannot satisfy these families.

4.1.2. ISSUES ENCOUNTERED DURING HDB GREENPRINT@YUHUA

The questionnaire also investigated the issues that were raised by HDB Greenprint@Yuhua. Although 74 percent of respondents replied in the survey that their life was undisturbed by the green retrofit program, the rest complained several issues. Particularly, noise disruption was the most critical issue as mentioned by 22 percent of respondents. This result echoed Zuo and Zhao (2014) who stated that noise was one of the negative experience with the construction of green buildings. Furthermore, some respondents complained the power supply to the estate was cut off at times due to the implementation of the retrofit works. A few respondents also complained that the green retrofit has affected their lift use as the bulky materials required by the retrofit were transported via lifts sometimes. These feedback from the respondents reminded the authorities and industry that some measures should be taken to minimize the negative impacts of the green retrofit.

Table 3: Respondents' Perceptions of HDB Greenprint@Yuhua and their Preferences for Individual Green Retrofit Programs

Code	Mean	*P*-value	Flat type (no. of rooms)					Size of household					Monthly household income (SGD)							Monthly household utility expenditure (SGD)					
			1&2	3	4	5 & Executive	*P*-value	1-2	3-4	5-6	≥7	*P*-value	<2K	2K-4K	4K-6K	6K-8K	8K-10K	>10K	*P*-value	<50	51-100	101-150	151-200	>201	*P*-value
A	4.10	0.000*	3.5	4.18	4.11	4.12	0.259	3.75	4.00	4.20	4.00	0.406	3.33	4.00	4.24	4.14	4.25	3.00	0.027#	3.67	4.10	4.25	3.83	3.00	0.035#
B1	3.95	0.000*	3.75	3.86	3.96	4.04	0.464	4.00	3.70	4.09	4.00	0.209	3.33	3.80	4.07	4.19	3.88	2.00	0.006#	3.33	3.97	4.14	3.67	2.00	0.005#
B2	3.73	0.000*	3.25	3.73	3.67	3.88	0.184	3.25	3.63	3.85	3.00	0.091	3.33	3.67	3.69	4.00	3.75	2.50	0.058	3.33	3.65	3.94	3.50	2.50	0.015#
B3	4.05	0.000*	3.25	4.09	4.15	4.04	0.031#	3.50	3.93	4.20	3.00	0.011#	3.33	4.07	4.07	4.29	4.00	2.50	0.005#	3.67	4.03	4.22	3.83	2.50	0.008#
B4	4.01	0.000*	3.00	4.14	4.04	4.04	0.005#	3.25	4.00	4.09	4.00	0.062	3.33	4.00	4.07	4.19	4.00	2.50	0.022#	3.67	4.03	4.11	4.00	2.50	0.061
B5	4.01	0.000*	4.00	3.95	4.04	4.04	0.911	3.75	3.89	4.09	5.00	0.143	3.33	4.07	4.07	4.05	4.25	2.50	0.019#	3.67	4.00	4.17	3.83	2.50	0.019#
C	4.09	0.000*	3.75	4.05	4.19	4.08	0.248	3.75	4.04	4.15	4.00	0.274	3.33	4.13	4.17	4.14	4.00	3.50	0.008#	3.67	4.10	4.17	4.00	3.50	0.072
D	3.30	0.000*	2.40	2.76	3.55	3.67	0.001#	2.80	3.03	3.51	3.00	0.071	2.17	2.59	3.38	3.75	4.00	3.00	0.000#	2.25	2.86	3.77	3.56	3.00	0.000#
E	1.52	0.000*	1.00	1.27	1.58	1.62	0.353	1.33	1.35	1.61	1.00	0.447	1.00	1.00	1.24	1.77	2.00	3.00	0.001#	1.00	1.32	1.58	1.63	3.00	0.245
F1	2.92	0.000*	2.50	2.55	3.15	2.88	0.368	3.00	2.47	3.14	1.00	0.022#	1.00	3.00	2.84	3.18	2.78	2.00	0.338	1.00	2.74	3.11	2.88	2.00	0.200
F2	4.48	0.000*	5.00	4.45	4.42	4.5	0.426	5.00	4.41	4.45	5.00	0.377	5.00	4.43	4.56	4.55	4.33	2.00	0.471	5.00	4.58	4.58	4.00	2.00	0.136
F3	3.25	0.000*	2.00	3.00	3.31	3.38	0.247	2.33	2.88	3.48	2.00	0.022#	1.00	3.29	3.04	3.64	3.22	2.00	0.031#	1.00	3.11	3.44	3.13	2.00	0.137
F4	3.89	0.000*	3.00	4.00	3.88	3.92	0.986	3.67	3.76	3.95	4.00	0.598	1.00	3.86	3.92	4.14	3.78	2.00	0.108	1.00	4.11	3.92	3.88	2.00	0.082
F5	3.42	0.000*	1.50	3.55	3.46	3.46	0.166	2.67	3.06	3.64	2.00	0.107	1.00	2.71	3.48	3.82	3.22	2.00	0.041#	1.00	3.47	3.5	3.38	2.00	0.289
F6	4.20	0.000*	5.00	4.09	4.31	4.08	0.269	5.00	3.94	4.23	5.00	0.043#	5.00	4.00	4.40	4.23	3.89	2.00	0.145	5.00	4.42	4.28	3.50	2.00	0.037#
F7	3.98	0.000*	4.00	3.91	4.12	3.88	0.585	4.00	3.88	4.00	5.00	0.204	3.00	4.14	4.04	4.05	3.89	2.00	0.078	3.00	4.11	4.08	3.63	2.00	0.012#
G1	4.08	0.000*	4.00	4.00	4.15	4.04	0.841	4.00	3.88	4.16	4.00	0.496	3.00	4.00	4.12	4.05	4.44	2.00	0.013#	3.00	4.11	4.14	4.13	2.00	0.046#
G2	3.37	0.000*	3.50	3.36	3.19	3.54	0.306	3.33	3.41	3.34	4.00	0.824	3.00	3.43	3.32	3.36	3.56	3.00	0.857	3.00	3.37	3.36	3.50	3.00	0.842
G3	4.05	0.000*	3.50	3.91	4.27	3.92	0.035#	3.67	4.00	4.09	4.00	0.537	3.00	3.86	4.12	4.00	4.44	2.00	0.007#	3.00	4.11	4.17	3.75	2.00	0.017#
G4	3.78	0.000*	3.00	3.55	3.88	3.85	0.045#	3.00	3.71	3.86	4.00	0.037#	3.00	3.43	3.68	4.00	4.00	3.00	0.038#	3.00	3.63	3.97	3.50	3.00	0.030#
G5	3.85	0.000*	3.50	3.55	3.88	3.96	0.059	3.67	3.59	3.95	4.00	0.210	3.00	3.71	3.84	3.91	4.11	2.00	0.030#	3.00	3.79	3.94	3.88	2.00	0.022#

Note: * The Shapiro-Wilk test was significant at the significance level of 0.05, suggesting that the data were not normally distributed.
The Kruskal-Wallis test result was significant at the significance level of 0.05, suggesting a significant difference among the households.

4.2. *RESIDENTS' WILLINGNESS TO EXTEND THE GREEN RETROFIT PROGRAM INTO INDIVIDUAL HOUSES*

The results of questionnaire showed that 4 percent of respondent were very willing to pay for the green retrofit in their individual houses, 52 percent were willing, 16 percent chose neutral, 25 percent were unwilling, and 3 percent were very unwilling to pay. This result indicated that, at least, the majority of the respondents had no objections to investing in the green retrofit in their individual households.

Despite the support from the majority, the Kruskal-Wallis test results in Table 3 showed that respondents' willingness differs significantly regarding their types of flats, monthly household income, and monthly household utility expenditure. Comparing to those living in big flats (i.e., 4-room, 5-room, and executive flats), those living in small flats (i.e., 1-room, 2-room, and 3-room flats) were less willing to pay for the green retrofit in their households. This was because residents living in small HDB flats were normally from the low-income group and thus they had no extra money to let their home undergo green retrofit. By contrast, the respondents with higher monthly household income were found more willing to undergo green retrofit as they were expecting to achieve a better living experience through the green retrofit in their homes. These results further echoed Swan et al. (2013) who had stated that the income levels would impact people's wills to engage with the sustainable retrofit agenda. Additionally, comparing to the respondents paying utility bills less than SGD 100 (USD 72), those paying SGD 100 or above were found more willing to undergo green retrofit. This was mainly because these respondents hoped to reduce their utility expenditures after the green retrofit.

4.2.1. RESIDENTS' WILLINGNESS TO PAY FOR THE GREEN RETROFIT IN INDIVIDUAL HOUSES

The questionnaire also examined the upfront cost the respondents were willing to bear for the green retrofit in their individual houses. The results showed that 58 percent of respondents were willing to pay no more than SGD 5K to have their houses undergo green retrofit, 31 percent of the respondents were willing to pay SGD 5K to 10K, 11 percent were willing to pay SGD 10K to 15K, and no respondents were willing to pay more than SGD 15K. Meanwhile, the Kruskal-Wallis test results showed that the upfront cost was statistically uncorrelated with the respondents' flat types, the size of household and monthly household utility expenditure, except for the monthly household income. It showed that the respondents with higher income were likely to spend more on green retrofit compared to the lower income group, which was consistent with the earlier finding that the higher income group was more willing to pay for the green retrofit in their individual houses.

4.2.2. RESIDENTS' KEY CONSIDERATIONS FOR THE GREEN RETROFIT IN INDIVIDUAL HOUSES

The questionnaire provided a list of seven considerations that may affect residents' involvement of green retrofit and requested the respondents to rate. Results in Table 3 showed that, the top four motivations for respondents to have their individual houses go green are: to achieve cost savings from lower utility bills in the long run (mean assessment = 4.48), the availability of financial assistance and green loans (4.60), saving the environment (3.98), and higher resale value (3.89). It is noteworthy that, among the top four motivations, three were associated with economic benefits the residents might gain, which suggested that economic considerations were still the top priority for most households to take into account when the decision of going green is assessed. Such findings echoed Darko and Chan (2016) who claimed that achieving economic benefits was one of the important goals for the authority, industry, and public to boost green buildings. By contrast, the bottom three motivations were the pride of owning a green home (mean assessment = 2.92), better aesthetic for home (3.24) and enhanced attractiveness for rental (3.41). Pride of owning a green home gained the lowest assessment, suggesting that residents were more interested in the substantial benefits brought by the green retrofit program. Better aesthetic for home received the second lowest assessment. This might be because green appliances bear a very similar resemblance to traditional household electronic appliances, and thus respondents may feel little or no change to the aesthetic of their homes. Enhanced attractiveness for rental is also not a significant motivation, referring to its third lowest assessment. This was because normally residents would not retrofit their houses just for the sake of increasing its rental attractiveness; instead, getting a better living experience and achieving some economic gains are the major impetus for residents to carry out the retrofit.

4.2.3. THE MOST PREFERRED GREEN FEATURES FOR THE GREEN RETROFIT IN INDIVIDUAL HOUSES

This study gathered five green features that were most commonly used in current green retrofit programs and requested the respondents to rate for their preferences. The Kruskal-Wallis test results in Table 3 showed that the respondents' assessments varied significantly regarding monthly household income and monthly household utility expenditure. These results are reasonable as the residents' preferences for the green features are highly associated with their financial situations (Swan et al., 2013). According to Table 3, the most popular feature was energy monitoring system with an assessment of 4.08, followed by LED lighting (4.05), low-flow water fixture (3.85), a dimmer switch (3.78), and low e-film window (3.37). Energy monitoring system was preferred because it allows homeowners to monitor the flow of energy throughout the entire home in real-time (Abubakar et al., 2017). LED lighting was preferred because it consumes up to 90 percent less power than those incandescent bulbs (Pelka and Patel, 2003). The third most preferred green feature was low-flow water fixture such as sink faucets, toilets, and shower heads that use less water per minute than those traditional and older models. It was favoured as it was a relatively low-cost and quick way for the individual household to conserve water and save money (Beal et al., 2013). Dimmer switch was the fourth most preferred green feature welcomed by the Yuhua's residents. Using a dimmer switch can prolong the life of the lighting appliances effectively and thus saving expenditures for the residents (Leslie, 2003). A low e-film window can reduce solar heat gain and radiant heat loss, creating year-round heating and cooling savings of up to three times as much as conventional window film with the comparable light transmission (Ismail and Henríquez, 2005). Nevertheless, it received the lowest preference. This might be because the benefits of e-film window could not reflect in the form of number economically so the residents refused to give a higher preference.

5. RECOMMENDATIONS TO REINFORCE THE EXISTING GREEN RETROFIT PROGRAM

Based on the findings of the questionnaire, three practical recommendations were put forward to reinforce the existing green retrofit program, as presented below.

5.1. ESTABLISHING A GREEN RETROFIT GUIDE FOR INDIVIDUAL HOUSES

The results of the questionnaire showed that more than fifty percent of respondents were interested in having their individual houses undergo green retrofit. Thus, a Green Retrofit Guide for Individual Houses might need to be established, to help those interested families carry out their retrofit works more easily and effectively. This guide should concentrate on those key elements that have high potentials for increasing the energy efficiency. Also, it should be able to function as a handy tool for building owners, facility managers, and consultants, which can guide these parties for retrofitting step by step, from building evaluation, target-setting, to the selection of suitable retrofit works, just like the Existing Building Retrofit Guide introduced by BCA (2010). Most importantly, this guide should involve the residents proactively before the commencement of the green retrofit work, so that the intents and requirements from the homeowners can be clear specified and understood, which can help achieve the success of the green retrofit program.

5.2. DEVELOPING A GREEN RETROFIT INCENTIVE PLAN FOR INDIVIDUAL HOUSEHOLDS

This study revealed that residents' willingness to install green features in their individual houses were affected by their financial capabilities. The respondents from the low-income families are reluctant to adopt green retrofit, while those from the high-income families showed greater interests. This result suggests that a green retrofit incentive plan for individual houses should be developed, to let households of all income groups have the equal chance to enjoy green and sustainable homes. Under this plan, the government should offer some incentives to low-income households. Furthermore, this plan should also urge financial institutions like banks to provide low-interest loans to individual households to facilitate them in retrofitting their individual houses.

5.3. UPGRADING THE GREEN HOME PACKAGE

As mentioned earlier in the Background section, the HDB Greenprint@Yuhua introduced a Green Home Package that allowed residents to purchase discounted appliances to lower their utility bills. Currently, the Green Home Package merely covers a large number of electrical appliances such as refrigerators, air-conditioners, LED televisions, washing machines, bulbs, and fans. However, the results of the questionnaire showed that the residents were also interested in some nonelectrical green features like low-flow water fixtures and low e-film window. Thus, the existing Green Home Package might need to be upgraded to include some non-electric stuff, such as eco-friendly windows, paints, papers, as well as the low-flow water fixtures installed in the kitchen or toilet. Also, the upgraded Green Home Package may consider developing an online portal, which will function as a convenient purchase platform to provide prompt and direct shipment for individual households and to recommend them qualified contractors for the in-house installations.

6. CONCLUSIONS AND RECOMMENDATIONS

Green retrofit has been proven to be a high-volume and low-cost strategy that can effectively improve the energy efficiency in those existing traditional buildings. Nowadays, it has become one of the most significant development activities ongoing in the existing building and construction industry. However, current literature shows that few studies have investigated the residents' perceptions of green retrofit programs. Thus, this study administered a questionnaire with the residents of a mature public residential estate of Singapore that just completed a pilot green retrofit program, to capture their perceptions of the program. Results showed that, despite minor problems like noise, power supply and lift disruptions, the majority of respondents were satisfied with the green retrofit program. In particular, outdoor LED lighting was assessed as the most preferred green feature, followed by pneumatic waste conveyance systems, rainwater harvesting systems, solar photo voltaic systems, and elevator energy regeneration systems. The questionnaire also explored residents' willingness to expand the green retrofit program into their individual houses. Results showed that more than 50 percent of respondents were supportive of having their individual houses undergo green retrofit and were willing to bear an upfront cost up to SGD 5K. It also disclosed the top four motivations that drive respondents to have their houses go green, which were achieving cost savings from lower utility bills in the long run, the availability of financial assistance and green loans, saving the environment, and higher resale value. Furthermore, results revealed that energy monitoring system was the most preferred green feature that the respondents would like to install in their houses, followed by LED lighting, low-flow water fixture, dimmer switch, and low e-film window. Lastly, this study came up with three practical recommendations to enhance the current green retrofit program. These recommendations were establishing a green retrofit guide for individual houses, developing a green retrofit incentive plan for individual households, and upgrading the Green Home Package.

Although the objectives of this study were achieved, some limitations were still present. First, this study collected opinion based data from respondents, which might be biased due to respondents' different perception patterns. Second, the findings from this study applied to Singapore exclusively, which may vary in other countries. In spite of these limitations, the findings from this study are still valuable, because they are the first-hand information concerning the residents' perceptions and expectations for the green retrofit program. Based on this fresh information, the authorities and industry can improve upon the current green retrofit program effectively. For the future research actions, an assessment model that gauges the energy efficiency of the green retrofit program could be developed. Also, it would be very interesting to explore the interrelationships between the residents' personal behaviours and the energy efficiency performances of their houses.

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BASIC ASSUMPTIONS OF CONTRACTOR'S SUB CULTURE IN PUBLIC SECTOR BUILDING CONSTRUCTION PROJECTS IN SRI LANKA

Aparna Samaraweera[1], Sepani Senaratne[2*] and Y.G. Sandanayake[1]

[1]Department of Building Economics, University of Moratuwa, Sri Lanka

[2]School of Computing, Engineering, and Mathematics, Western Sydney University, Australia

ABSTRACT

Contractor is considered as a dominant construction project participant, contributing to the construction project culture. Identifying the basic assumptions of contractor's professional sub-culture at project level could be worthwhile for better management of construction projects since, cultural differences among project participants could create risks of conflicts and dissatisfactions owing to underperformance of construction projects. Thus, this research aims to derive basic assumptions of contractor's sub culture in public sector building construction projects in Sri Lanka. The aim was approached through an exploratory case study research design. Three public sector building construction projects were selected as the cases using construction project culture as the unit of analysis. Cases were restricted to traditional method contracts and team setting to public sector clients and consultants and private sector contractors. Nine semi-structured interviews, observation of two progress review meetings and documentation review per case were used as the data collection techniques. Solutions for internal integration and external adaptation problems of each project team was questioned during data collection. Code based content analysis was used in data analysis. Findings revealed the existence of dominant professional sub-cultural groups of client, contractor and consultant within construction projects. Group boundaries were indicated by each party trying to defend themselves as a group and having matters which they thought not suitable disclosing to other parties. The basic assumptions of the contractor's sub culture were identified with regard to the eleven cultural dimensions of; nature of human relationships, nature of human nature, nature of reality and truth, nature of human activity, nature of time, acceptance on homogeneity or diversity, unknowable and uncontrollable, gender, motive for behaving, state-individual relationship and, organization's relationship to its environment. These findings are important for project managers for better understanding of the unique cultural behaviours of contractors to avoid any interpersonal conflicts among contractor's personnel and other team members.

Keywords:*Basic Assumptions; Construction Projects; Contractor's Sub-Culture; Sri Lanka.*

1. INTRODUCTION

Construction project team is formed with different participants such as consultants, contractors, client and other stakeholders from different organisations. Many difficulties seem to arise due to the conflicts of different business objectives and lack of sensitivity and tolerance between these participants. (Fellow *et al*., 2007). Many of these differences creating risk of conflicts and dissatisfactions are owing to cultural differences of construction project participants (Tijhuis, 2011; Ankrah and Langford 2005). Among these different construction project participants, contractor is identified as a dominant participant influencing project culture (Ankrah *et al*., 2009). Rameezdeen and Gunarathna (2003) elaborate the cultural differences between contractor and consultant organisations in Sri Lanka. According to these authors, consultants believe that their success depend on the development of human resources for achieving specific goals of the organisation which emphasises on a culture with loyalty, value traditions and openness. In contrast, contractors are driven towards output maximisation, where they encourage a competitive work environment and culture among contractor's personnel. Moreover, Ankrah and Langford (2005), who study on architectural and contracting organisations

*Corresponding Author: E-mail – s.senaratne@westernsydney.edu.au

in Scotland explain that major differences exist in these two types of organisations, not only pertaining to their structures, but also in people issues. Authors declare that major differences exist among architects and contractors in aspects such as; organisation, rationalisation and standardisation of tasks, sources of power based on relationships with managers, control and coordination mechanisms, degree of formality, tolerance of ambiguity and need for recognition. Thus, these studies indicate that contractor has a distinct cultural demonstration compared to other construction project participants. It is apparent that the aforementioned studies attempt to capture these distinctions of the contractor at organisational level only. There can be differences in cultural manifestations of the contractor's personnel, when they start working with other stakeholders in a project at operational level, in contrast to their manifestations at their organisational context. Thus, a specific focus into the contractor's cultural manifestations at project level in a study could be worthwhile for better management of construction projects. Understanding cultural differences between sub-cultures could help removal of misunderstandings among sub-cultural members (Gajendran *et al*., 2012). Similarly, such an understanding could be helpful for construction project managers for conflict resolution and managing relationships among project participants.

More importantly, the biggest flaw in the aforementioned studies is the lack of consensus on what cultural manifestation better describe the culture at project level. The long list of cultural manifestations includes artefacts, norms, behaviours, values, basic assumptions and so on (Martin, 2002). However, only a limited number of researchers highlight the importance of studying the inner layers of a cultural context which include values and basic assumptions. Schein (1984, 2004) brings forward empirical evidence to convince the necessity of studying the basic assumptions of a cultural context, since basic assumptions are the real essence of culture. Learning basic assumptions gives way to interpret any of the other given cultural manifestations too. Hills (2002) brings in empirical evidences on how knowledge on cultural basic assumptions could be helpful for successful negotiations between different cultural groups. It is expected that studying basic assumptions of the contractor could add value to negotiation efforts with contractors in construction project teams too. Thus, this study aims to derive basic assumptions of contractor's sub culture in public sector building construction projects in Sri Lanka and basically attempts to answer two Research Questions (RQs), RQ1: What are the evidences available for sub-cultural existence in construction project culture? and RQ2: What are the underlying basic assumptions of contractor's sub-culture?. This paper presents a part of a bigger study, which attempts to derive the underlying basic assumptions of contractor, consultant and client to determine the public sector construction project culture in Sri Lanka.

2. SUB-CULTURAL EXISTENCE AND CONTRACTOR'S SUB CULTURE IN CONSTRUCTION PROJECTS

Many researchers acknowledge the existence of strong sub-cultures in most cultural settings. Kumaraswamy *et al*. (2002) identify 'organisational', 'professional', 'operational' and 'individualistic' sub-cultures as the principal elements that come together to evolve the culture within a construction project. According to their explanations, 'organisational sub-cultures' are mainly influenced by national culture and industry culture, 'operational sub-cultures' are comprised of quality culture, safety culture, and learning culture, 'individualistic sub-cultures' are influenced by factors such as national culture, ethnic factors, social status and religion and 'professional sub-cultures' are influenced by the type of members, origin and history and type of task/function. Accordingly, Kumaraswamy *et al*. (2002) highlight the existence of sub-cultures based on the numerous projects participants and their specific roles within the project. Similarly, Liu and Fellows (1999) indicate about the existence of cultural differences among various professionals in construction projects. Pheng and Alfelor (2000) indicate that managing these differing professional cultures is a challenge to construction project managers.

Schein (1996) brings forward another interpretation of sub-cultures related to different occupations within an organisation, but not specifically for construction context yet, in generic grounds. These sub-cultures include: 'engineers' (technocrats) who design and monitor the technology for supporting an organisation's operations; 'operators', who deliver products and services and, 'executives' who primarily focus on financial performance. These sub-cultures are called 'engineering sub-culture', 'operator sub-culture' and 'executive sub-culture' respectively. According to Schein (1996), organisational learning and change failures are primarily due to inadequate understanding of occupational sub-cultures existing within organisations. It is because these occupational sub-groups hold different views and interpret differently the same aspect due to the difference in their professional background, which results in communication problems. Chapman *et al*. (2011), empirically support this concept of occupational sub-cultures proposed by Schein (1996) by using the same concept in a cultural analysis of some organisations in the United States and Australia. However, their selection of individuals for each sub-culture group is based on: job titles such as chief executive officer, vice president and senior manager classified as 'executives'; job titles such as consultant, project manager and sales representative as 'operators', and job titles such as engineer, information technology analyst and operations manager as 'engineers'.

Going in line with the explanations by Schein (1996) and Chapman et al. (2011), it could be argued that even a construction projects could include similar occupational or professional sub-cultural groups (refer Figure 1).

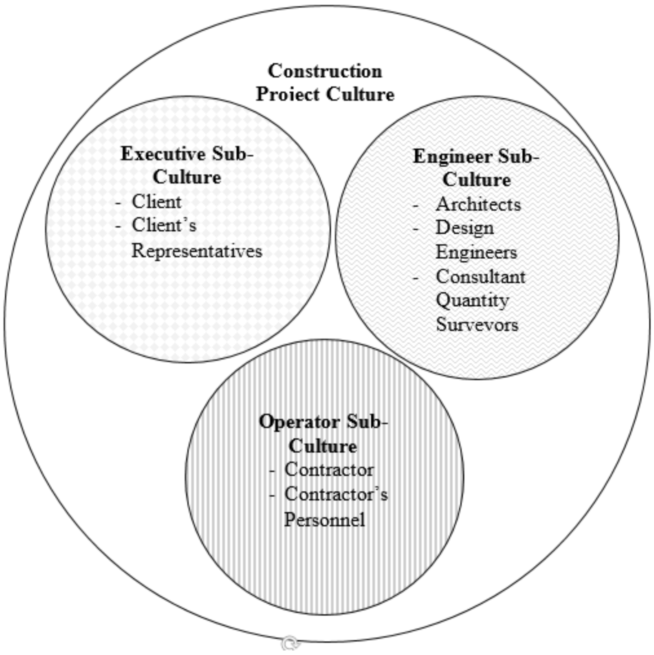

Figure 1: Sub-Cultures in Construction Project Culture

Accordingly, client and client's representatives can be identified as the 'executive sub-culture', since this sub-cultural group is more concerned on financial performance of the construction projects. Consultants including architects, design-engineers and consultant quantity surveyors can be identified as the 'engineer sub-culture', since they are more into design aspects, working mainly with technical backgrounds. Moreover, contractor's personal can be identified as having similarities with 'operator sub-culture', because they are the group that really struggle at the filed with labour, plant material to realise the construction output.

3. Basic Assumptions as a Cultural Manifestation

Schein (2004, 1990) describes that cultural manifestations can be identified in three levels as; 'visible artefacts' in the primary level, 'espoused values' in the next level and 'underline assumptions' in the highest level giving the proper interpretation to the exact organisational culture. It is the values of an individual or a group that lead to behaviour and when the behaviour begins to solve the problem, which led the behaviour in first instance that value is transformed into a basic assumption. Schein (1983, 1984) explains basic assumptions as mostly unconscious and are taught to new members as a reality and as the correct way to view things. Values become apparent by interviewing key members of the organisation to identify the reasons for the behaviour of the members. Nevertheless, he argues that to really understand the culture, it is important to identify the underlying assumptions. In addition, Hofstede (1980) also refers these underlying assumptions as 'taken for granted values'. Thus, underlying assumptions or otherwise called taken for granted values are considered as the core of the culture or the essence of the culture (Schein, 1984).

The Value Orientation Theory (VOT) by Kluckhohn and Strodtbeck (1961) is one of the theories that best describes the value content of culture. Many of the researchers who made the attempt to capture the taken for granted values or the basic assumptions of culture in cultural interpretations have followed the work of Kluckhohn and Strodtbeck (1961) (see Schein, 1984; Hofstede, 1980). It is important to note that though the term 'values' is used in a more generic manner in this theory, it refers 'values' specifically for 'taken for granted values', thus the basic assumptions of human kind. Such basic assumptions identified in generic individual and organisational studies by Schein (1983) and Hills (2002), which are possibly available in contractor's sub-cultural context are described in Table 1. According to Table 1, basic assumptions are presented in question form. A selected answer from the 'Possible Answers' to the 'Questions to be Answered' demonstrates a basic assumption of the contractor's sub-culture. For example, if the selected answer by the contractor's sub-culture is 'dominant' for the question 'what is the relationship of construction project to its environment?', then 'the relationship of construction project to its environment being dominant' is identified as an underlying basic assumption of contractor.

Table 1: Proposed Underlying Basic Assumptions of Contractor Sub-Culture

No:	Dimensions	Questions to be Answered	Possible Answers
1	The nature of human relationships	In what way construction project team members relate to each other for distribution of power and affection?	- Competitive - Cooperative
		What is the best way to organise the project team?	- Individualism - Groupism
		What is the best authority system for a construction project team?	- Autocratic/paternalistic - Collegial/participative
2	The nature of human Nature	What is construction project considers the nature of human nature to be?	- Good - Neutral - Evil
3	The nature of reality and truth	What is the way reality and truth are defined by the construction project?	- Pragmatic test - Reliance on wisdom - Social consensus
4	The nature of human activity	What is the nature of human activity of construction project team members?	-Dominant/pro-active - Harmonizing - Passive/fatalistic
5	The nature of time	What is the most relevant time unit for the construction project?	- Past - Present - Future
6	Homogeneity vs. diversity	Is the construction project team best off if it is highly diverse or if it is highly homogeneous,	- Diverse - Homogeneous
		Should individuals in in the construction project be encouraged to innovate or conform?	- Innovate - Conform
7	Unknowable and Uncontrollable	Do we tend to believe in fate/god or not?	- believe in fate/god - do not believe
8	Gender	How should society distribute roles, power and responsibility between the genders?	- Male - Female - Both
9	Motive for Behaving	What should be the motive for behaving within the project context?	- Doing - Being - Being-in-Becoming
10	The State-Individual Relationship	Should precedent right and responsibility be accorded the nation, individual or both?	- Nation - Individual - Both
11	The organisation's relationship to its environment	What is the relationship of construction project to its environment?	- Dominant - Submissive - Harmonizing - Searching out a niche

(Adapted from Schein, 1983 and Hills, 2002)

As described by Schein (2004), in order to extract the underlying basic assumptions of a cultural group, it is required to question on internal integration and external adaptation problems of that group. Internal integration problems include: what is the group adopted language?; how group boundaries are decided upon?; how power and status are decided upon?; to what extent close relationships are appreciated among member?; how rewards and punishments are decided upon? and, what ideologies exist?. External adaptation problems include: how strategy and goals are decided upon?; what means of accomplishing goals are adopted?; how performance is measured?; and, what corrective actions are adopted?. The solutions adopted by the cultural group for such problems could be analysed inductively to identify each basic assumption. Once this is done, it would be apparent that there is a deeper level of assumptions, which ties together the various solutions to these various problems (Schein, 1983). This deeper level deals with more ultimate questions as described in Table 1.

4. METHODOLOGY

This research basically attempts to answer the two research questions; RQ1: What are the evidences available for sub-cultural existence in construction project culture? and RQ2: What are the underlying basic assumptions of contractor's sub-culture?. According to Yin (2009), 'what' type of research questions support exploratory case study research designs. Therefore, case study was identified as the research strategy for this research. Three public sector building construction projects from Sri Lankan context were selected as the cases considering 'construction project culture' as the unit of analysis. According to Eisenhardt (1989), number of cases to be decided on the basis of theoretical sampling and not based on statistical sampling. Therefore, theoretical sampling method was adopted to select the three cases expecting literal replications. Data collection techniques included semi-structured interviews, observations and documentary survey for effective data triangulation. Semi-structured interviews were carried out with the participation of selected nine project team members from each case including three members from contractor's personnel (private sector contractors), three members from client's personnel (public sector clients) and three members from consultant's personnel (public sector consultants). A total of 27 interviews were conducted from all three cases. Observations were mainly done by participating at least two progress review meeting of each selected project including data recording following a progress review meeting observation guideline. Data were collected from contract documents and two progress review meeting minutes during the documentary survey. A pilot case study was carried out to refine the interview guideline and the progress review meeting observation guideline and to check the robustness of the questions and observation areas included. This pilot case study also acted as a pre-test for the interview and observation process. Data collection was done to indirectly question and observe the cultural context, in order to extract the underlying basic assumptions of the construction project culture considering the scope of the bigger study this paper is based on. However, this paper presents only the findings to RQ1 and RQ2. Further, both within-case analysis and cross-case analysis were done using code based content analysis during the data analysis process. A pattern-matching (Yin, 2009) effort is presented in the discussion at Section 6 for theoretical generalisation purposes.

5. CASE STUDY FINDINGS

Background details of the cases are given in Table 2.

Table 2: Background Details of the Cases

Case	Project A	Project B	Project C
Type	Extension to a ministry headquarters	Government hospital building	Administration building of a government commission
Project Cost (Sri Lankan Rupees)	1317 millions	500 million	800 million
Project Duration (Construction Phase)	21 months	24 months	30 months
Physical construction progress by the time of data collection	65%	70%	60%
Procurement Method	Traditional method with measure and pay contract	Traditional method with measure and pay contract	Traditional method with measure and pay contract
Past Working History	Contractor and Consultant had worked together for a previous building project	Consultant had worked for same Client's previous renovation project	Contractor had worked for the same Client's previous renovation project

Findings are presented in answering the RQ1 and RQ2 in sub-sections 5.1 and 5.2 respectively.

5.1. SUB-CULTURAL EXISTENCE IN CONSTRUCTION PROJECTS

Clear evidences for sub-cultural existence as; contractor's sub-culture, consultant's sub-culture and client's sub-culture were available within Projects A, B and C. These evidences were tracked both during interviews and during progress review meeting observations. Such evidences were related to existence of group boundaries in each sub group such as each party trying to defend themselves as a group and having matters which they thought not suitable disclosing to other parties. These behaviours had created the insiders and outsiders to each sub-group of client, contractor and consultant.

For example, although everybody worked as a single project team, when the Construction Manager of the Contractor of Project A was questioned about any differences among the parties in treating subordinates, he mentioned that he felt everybody in the project team was trying to protect each party in every occasion. This was clearly observed by the researcher during progress review meetings too. During 32nd progress review meeting, Consultant Project Design Engineer was asked by the Client about the date the design of connection bridge from existing building to new building was given to the contractor. By that time, even Consultant Project Architect joined explaining about the dates and the adequacy of the details given in favour of the Project Design Engineer. A similar situation was observed in contractor's group of Project B too where, Project Coordinator and Construction Manager both adding to the answer of the Contractor's Electrical Engineer over a matter about material approvals for data cabling. Progress review meeting was considered by the team members as a place to raise issues and defend themselves as sub-groups of the project team. Thus, this strong division as client, contractor and consultant could clearly develop unique values, which could later turn into basic assumptions of each sub-group.

Further, it was evident that there were matters related to the project that each party kept away from the other parties. In all three cases, contractor and consultant had kept their weaknesses hidden from others creating major boundaries between the groups. As explained by the Project Manager of Project A, who was a member of the Consultant's group mentioned that Consultant was having delays in the design works due to lack of staff. However, initially they were reluctant to give this reason to Client, but later they had explained it when they felt things getting worse if not revealed to the Client. As explained by the Project Manager, sometimes he was in a very uncomfortable situation as he could not explain some weaknesses of Consultant to Client directly. This was because, he was from the same Consultant's party and the duel responsibilities residing with him to his organisation and the Client.

Similarly, Site Engineer of the Contractor of Project C specifically mentioned that they try to keep their internal matters away from the rest of the project team. Both Consultant Project Architect and Project Manager mentioned that the internal problems of contractor due to lack of labour force was kept hidden until such matter become obvious to both Client and Consultant. Even Contractor had gone to an extent of keeping formal written communication mode with Consultant and Client considering them as outsiders to their sub group and emails and other less formal communication modes with their domestic specialised sub-contractors, considering them as insiders. Accordingly, there were such strong evidences for the existence of sub-cultural groups in construction projects.

5.2. BASIC ASSUMPTIONS OF CONTRACTOR'S SUB-CULTURE

The similarities and differences of the abstract basic assumptions across the three case; Cases A, B and C for contractor's sub-cultural group are analysed in this sub-section and summarised in Figure 2.

Abstract Basic Assumptions of nature of human relationships – Contractors in all three cases held the abstract basic assumption of 'autocracy' as the best authority system within the construction project. They did not specifically concerned about whether such autocracy should be from the client or the consultant. However, they preferred an autocracy of an unbiased and dedicated leader. It was apparent in all cases that contractor got demotivated in the project context due to going against this abstract assumption of the contractor with the absence of an unbiased and dedicated leader.

Contractors A and B held the abstract assumption of 'groupism' as the best way to organise the project society. In contract, Contractor C assumed 'individualism' as the best way to organise the project society. Contractor C having most previous experience in working for design and build contracts was trying to strictly adhere only to the construction responsibility in Project C with traditional method. However, both the Contractors A and C considered their previous experience with Consultant A and Client C respectively, when organising the teams, demonstrating their preference for ‘groupism’, unlike the consultant.

All contractor assumed ‘competition’ as the correct way to relate to each other, to distribute power and affection within project context. This was due to the power structure existed in construction projects within Sri Lankan construction industry, placing the contractor in the lowest position in terms of power. Thus, contractor constantly attempted to defend themselves from the suppressions of consultant and client and gain some power within the project team. This amounted to the competition, when contractor tried to relate to each other.

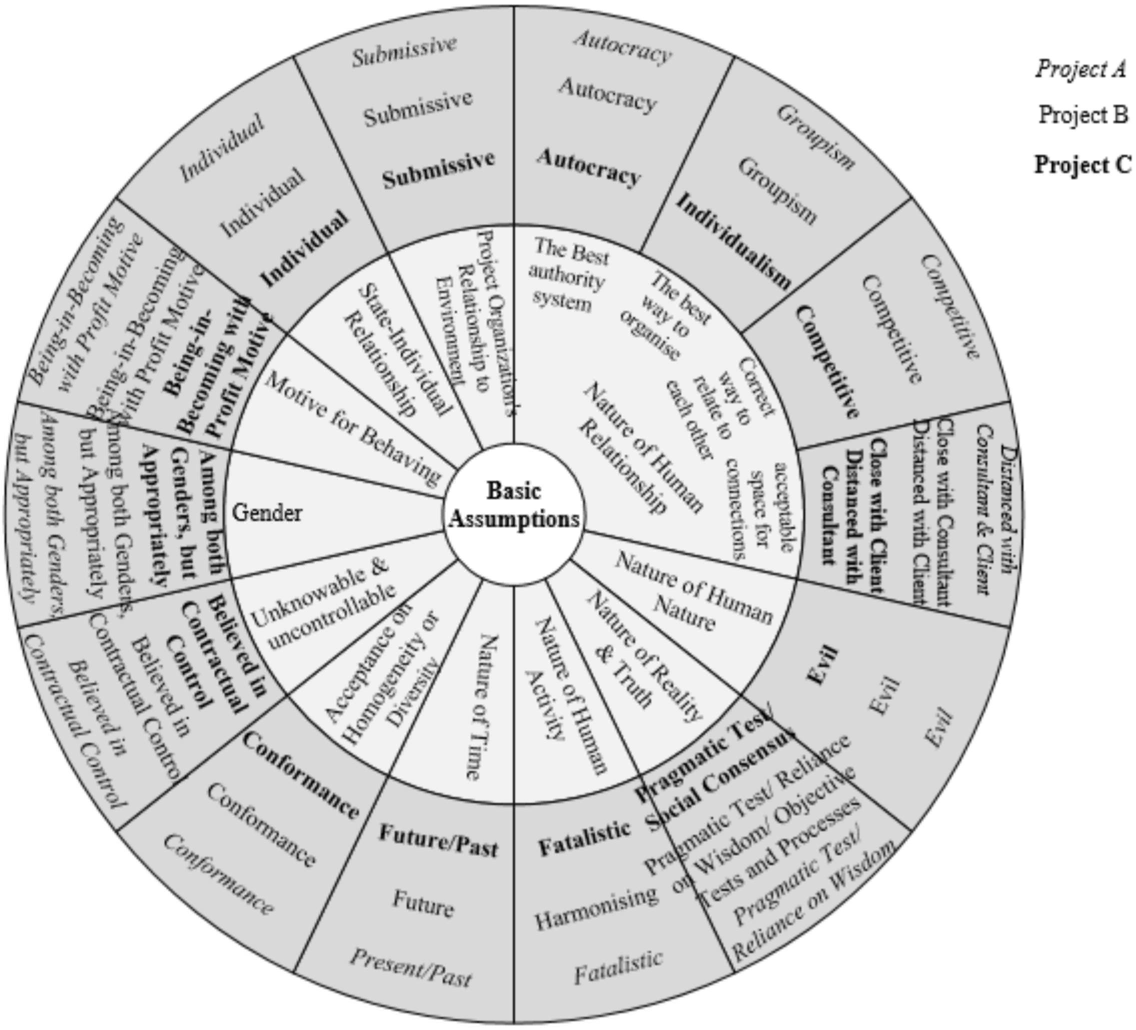

Figure 2: Basic Assumptions of Contractor’s Sub Culture in Projects A, B and C

In addition to the three perspectives discussed above, another perspective could be identified for the determination of the nature of human relationship through case data. This was about looking into what was the acceptable space for cognitive, emotional and behavioural connection. The acceptable space could be either close or distanced. Contractor A did not prefer any close connection with consultant or client, Contractor B preferred close connections with the consultant and Contractor C preferred close connections with the client. There was no apparent reason for the contractor in determining the acceptable space for cognitive, emotional and behavioural connections among team members and was solely based on their personnel preferences. Necessity, preference and mutual trust of both parties at the same time for such a close connection made the possibility of emergence of a close connection. Although, Contractors A and C had previous work relationships with their respective consultant and client, only Contractor C wished to maintain a close connection, indicating no effect of previous work experience contributing for developing close connections. In addition, there was no relationship of strategic competitive advantage of contractor organisation affecting the development of close connections too. Contractor B, who had a close connection with the Consultant B indicated that having such a connection was advantageous but, not acceptable in the industry practice. This was because, it was suspected that such a close connection could affect the impartial behaviour expected from a consultant. Further, Contractor C, who had a close relationship with Client C mentioned that having a close connection was advantageous, but not much acceptable in the industry. This was because, if consultant was appointed as the 'Engineer' to the construction contract, informal relationships could affect the formal instruction and communication flows indicated in standard construction contracts. Notably, when close connections existed, contractor demonstrated some cooperative beliefs on relating to each other, to distribute power and affection. However, they could not completely refrain from the competitive nature. Power struggle, still kept them busy in competition.

Abstract Basic Assumptions of nature of human nature – Contractors in all three cases held a strong abstract basic assumption of nature of human nature being 'evil'. Contractor normally did not receive appreciations or rewards within the team setting and complaints, punishments and criticisms were common in the project setting. Further, contractor lacked trust with other team members too. Contractor regarded meeting room as a place to discuss issues and defend themselves. This was evident during the meeting observations of all three cases. No any direct appreciation for the Contractor from Client or Consultant was witnessed by the researcher. All meetings and meeting minutes were full of problems, issues and lapses and indications on who was responsible and what actions to be taken to overcome those. Contractor's Project Manager of Project B mentioned that they absorbed many ill-treats by the Client and Consultant considering the maintenance of good relationship among the team members. He further elaborated that one reason for lack of appreciations by the Consultant may be because, it could be misunderstood by the Client as Consultant being bias to the Contractor.

Abstract Basic Assumptions of nature of reality and truth – Contractor preferred more subjective means of determining the reality and truth in project context. All contractors of Projects A,B and C commonly agreed 'pragmatic tests' as the best way to define what was true and what was not in project matters. In addition, Contractor A and B relied on wisdom too, pertaining to their ability to bring in strong arguments due to the maturity in industry. Moreover, Contractors B and C looked for 'social consensus', in addition to the other means, due to their organisational competitive strategic advantage being strong human relationships. They preferred the consensus of the consultant and client for making decisions as it improved the relationships. However, Contractor A and C believed that consultant assumed 'objective tests and processes' as the best way of determining the reality and truth in project context, in contrast to their belief on subjective means of determining reality and truth.

Abstract Basic Assumptions on nature of human activity – Contractors A and C, held the abstract assumption that being 'fatalistic' as the correct way for humans to behave within project context. The reason for this was because that being in the maturity stage of their organisational development, they had learnt to accept and obey pressures and forces from the project environment well. They were appeared to be more reactive than proactive in nature too. However, Contractor B, who was at the growth stage of organisational development, tried to harmonise with other team members, until they position themselves in the market. They did not carry the fantastic assumptions. The general power structure in a typical construction project in Sri Lankan construction industry existed in the order of contractor constantly placed with a very low power compared to client and consultant. This too had contributed to contractor refrain from being dominant and remain as either harmonising or fatalistic. The power order of client and consultant depended on client being the most powerful, when client was politically powerful or highly professional with educated background and consultant being the most powerful, when client was a layman, depending on consultant.

Abstract Basic Assumptions on nature of time – Contractors A and C, who had previous work experience with the consultant and client respectively, based their decisions of the current project involved on such past experiences. Both the contractors had considered appointing the most staff, especially the senior staff from the previous project as a strategic decision. This was to use the advantages of learned lessons in past relationships to the current projects. This indicated the contractor's abstract basic assumption of 'past' as a relevant time unit for the conduct of daily affairs in the project. In addition, Contractor A based most of other decisions on 'present' only. This was because, they did not see any advantage of considering future in their decisions, as the organisational competitive strategic advantage of Contractor A was on quality of output only. They never felt a necessity of continuing relationships with clients or the contractors. They believed that clients will come to them considering their differentiated work output and service. However, in contrast, Contractors B and C considered 'future' as the most relevant time unit for other decisions. This was mainly because, organisational strategic competitive advantage of Contractors B and C was long term relationships with clients and consultants. Thus, they compelled to try out continuing relationships with other members.

Abstract Basic Assumptions on Acceptance on Homogeneity or Diversity – Since construction project teams were compulsorily diverse in nature, whether team should be highly diverse or homogeneous was not a concern in construction project context. However, contractors in all three cases strongly believed that individuals in the public sector construction project team were encouraged to conform and not to innovate. Contractor A brought in reasons for strict belief on conformance as time pressure and consultant and client preferring adherence to contract conditions including specification and drawings. However, no innovations were tried out at least to accelerate the project works and still followed all complex and time consuming documentation procedures with shop drawings. Contractors B and C too indicated that consultant and client required the strict conformance to project specifications and never tolerated any deviations. They indicated the difficulty of getting payments done, when not adhering to contract specifications. Construction contracts in all three projects included a contract clause for value engineering, which gave some provision for innovation for contractor. However, none of the contractors had used these condition for innovations.

Abstract Basic Assumptions on Unknowable and Uncontrollable – With regard to unknowability and uncontrollability, contractors in all three cases never solely depended on fate. They always believed on ‘contractual control’ in the uncertain project environment. They supposed that the decisions made by public sector clients were mostly uncertain and variations were unavoidable to a greater extent. However, adherence to construction contract by following contract clauses and maintaining evidences in black and white had always reduced their risks with uncertainties. All contractor’s held the idea that the ultimate responsibility of time, cost and quality of the project resided with the contractor. Contractor of Project B highlighted that considerable number of small scale disruptions happened from the Client, which could not get compensated from the Client practically. They believed that ultimately, not everything could be claimed from the Client.

Abstract Basic Assumptions on Gender – Contractors in all three cases held the abstract basic assumption that distribution of roles, power and responsibilities should be among both genders, but appropriately. Contractor of Projects A and C believed that it was the attitudes that mattered in allocation of responsibilities to any gender. They were specifically concerned on attitudes of females since, they believed females lacked interest on obtaining practical construction experience by working on sites, which was an essential for any employee working under a contractor. However, Contractor B specifically mentioned that females had different capabilities and talents such as for documentation, compared to males, which could be effectively considered in team selection. It was noted that quantity surveying task of Projects A and B was mainly done by females, may be due to the same reason.

Abstract Basic Assumptions on Motive for Behaving – The motive for behaving of contractors in all cases were into being-in-becoming. They strived to develop, change grow and be better. All the contractors indicated the signs of necessity on continuous development, identifying the lapses in their systems and processes. Contractor A, based on an organisational competitive strategic advantage on quality of output, always considered providing a better quality construction output. Contractors B and C, holding on to the organisational strategic competitive advantage of maintaining long term relationships with clients and consultants, strived on building up the relationship. However, all were possessing the urge to make profits, being profit oriented commercial organisations. Thus, the motive for behaving of the contractor was into ‘being-in-becoming with profit motive’.

Abstract Basic Assumptions on State-Individual Relationship – All contractors in the three cases believed that the precedent right and responsibility should be accorded the ‘individual’, despite they were working for public sector construction project. This was mainly because, contractors were from private sector organisations with profit motives, where they were into satisfying the client’s individual interests and making a profit, rather than believing on delivering a product to the nation. The strategic competitive advantage of Contractors B and C being long term relationships with clients, it was evident that those contractors were putting in a specific effort to satisfy the client even though the client’s requirements were not reflecting the best for a public building with regard to the public funds being spent and the expected functionality of the building. For example, in Project B, doctors being end-users requested for luxury types of finishes for their rest room areas, for which contractor attended providing the same without any hesitation, though consultant criticised such client requirement as not fitting for a public building.

Abstract Basic Assumptions on Project Organization's Relationship to its Environment – All contractors in the three cases believed that the project organisation's relationship to its external environment was 'submissive'. This was because, contractor was in a constant battle with the external environment in procuring labour, plant, good, works and services for the project functions, facing financial issues, lack of resources and consequences of poor systems and process, which had rooted into their minds that the project organisation was submissive to the external environment. Many of the project level issues stemmed out from the issues at contractor's organisational level, which they were unable to control of their own.

6. DISCUSSION

In pattern matching, it was identified that some of the research findings on contractor's basic assumptions at project level were in line, while some were contrasting to the Sri Lankan contractor's organisational cultural orientations identified by Rameezdeen and Gunarathna (2003). Contractors believing on correct way to relate to each other to distribute power being competitive was in line with competitive orientation towards rivals as described by Rameezdeen and Gunarathna (2003). Assuming that the best authority system being the autocracy of an unbiased and dedicated leader being in line with the explanations on considering leaders as hard-drivers. However, according to the case study findings, within project cultural context, contractors were more collective in project organisation. However, according to Rameezdeen and Gunarathna (2003), contractors emphasise goal achievement over team work. Further, case study findings did not indicate contractors being innovative and valued conformance the most.

Further, in comparison of the case study findings with the elaborations of Ankrah and Langford (2005) on cultural orientations of Scottish contractors, Sri Lankan contractors at project cultural were not always formal. Their basic assumptions on acceptable space for cognitive, emotional and behavioural connection were vaguely close and distanced according to their personal preferences. Moreover, Sri Lankan contractors were more of fatalistic in behaviour, in contract to the proactive attitudes held by the Scottish contractors. However, Sri Lankan contractors too preferred high direction as Scottish contractors preferring the autocracy of unbiased, dedicated leader.

7. CONCLUSIONS

This research intended to answer the two research questions RQ1: What are the evidences available for sub-cultural existence in construction project culture and RQ2: What are the underlying basic assumptions of contractor's sub-culture. In answering the RQ1, case study findings revealed the existence of professional sub-culture of contractor, consultant and client. Group boundaries were indicated in each sub group such as each party trying to defend themselves as a group and having matters which they thought not suitable disclosing to other parties. These behaviours had created the insiders and outsiders to each sub-group of client, contractor and consultant.

In answering RQ2, underlying basic assumptions of the contractor's sub-culture was identified related to eleven cultural orientations. Several assumptions varied across the three cases subjected to some situational factors. The basic assumptions of the contractor's sub-culture as agreed across all three cases included: the best authority system being autocracy of an unbiased and dedicated leader; the best way to organise the project society being groupism; the correct way to relate to each other to distribute power and affection within project context being competitive in behaviour; nature of human nature being evil; reality and truth to be defined within project context by subjective means; individuals in a project team to be encouraged to conform; faith to be kept in contractual control; project society should distribute roles, power and responsibilities among both genders, but appropriately; the motive for behaving to be being-in-becoming with profit motive; precedent right and responsibility be accorded the individual and, project organisation perceive itself to be submissive to its environment. The varied assumptions across the three cases included: the most relevant time unit being past, present or future; the correct way for humans to behave within project context being fatalistic or client, consultant dominance and, the acceptable space for cognitive, emotional and behavioural connection to be close or distanced.

These findings would be useful for project managers for better understanding of the unique cultural behaviours of contractors to avoid any interpersonal conflicts among contractor's personnel and other team members and help contractor to integrate properly with other team members. Further research directions include developing guidelines for better negotiations with contractor during change initiatives using the underlying basic assumptions derived through this research.

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BIM AND OPTIMISATION TECHNIQUES TO IMPROVE SUSTAINABILITY IN GREEN CERTIFICATION SUBMISSION OF CONSTRUCTION PROJECTS

Guomin Zhang[1] and Malindu Sandanayake[2*]

[1]Department of Civil and Infrastructure Engineering, RMIT University, Melbourne, Australia

[2]Department of Building, Victoria University, Melbourne, Australia

ABSTRACT

Green Buildings are gaining popularity in the construction industry as a result of strict environment protocols and carbon neutral policies by the governments across the globe. In Australia alone, since the introduction of Green Star Certification 5.5 million square metres of buildings have been certified as green buildings. With more stakeholders involved, the green certification submission process has become more complicated with less focus on triple bottom line approach of sustainability. Research has shown that 85% of the green submissions are concentrated on environmental sustainability with less significance on economic and social aspects. Building Information Modelling (BIM) is a cutting-edge technology that allows effective decision making. The proposed research aims to develop a BIM model that can improve the sustainable decision making during green certification processes. Multi-objective optimisation techniques were developed to optimise the best design solution for different design criteria. A case study is employed to verify the functions of the platform suggested in the study. The results of the case study indicated a combination of green design options provide a maximum of 4.54% GHG emission reduction per unit cost increase. The outcomes of the research will be important to organizations who are keen on improving the environmental sustainability while minimising the economic implications.

Keywords:*Building Information Modelling; Cost; Green Buildings; Greenhouse Gas; Sustainability.*

1. INTRODUCTION

In Australia, the construction industry contributes to around 100 billion dollars to the country's Gross Domestic Product (GDP) and employs around one million people, which account for 7.8% of Australia's GDP and 9.1% of the workforce, respectively (Statistics, 2015 ; Love et al., 2005). Buildings are known contributor for energy consumption and environmental emissions throughout the life cycle. Research studies emphasize that decision taken during the design and conceptual stages will have more influence on reducing environmental emissions and energy consumption. The concept of green building was introduced to acknowledge the concept of sustainability by optimising the energy consumption and resource usage to minimise life cycle environmental impacts. In the current scenario, contractors and designers are in constant search for advanced technologies and new materials to improve the environmental performance of buildings. Despite these efforts research studies emphasize several impediments that restrict the opportunity to benchmark a particular green material or green construction technology.

Green Star rating system is the official rating system developed by Green Building Council of Australia (GBCA) to rate the buildings based on the environmental performance. Since the introduction of the rating system, 5.5 million square metres of buildings have been certified by GBCA as buildings. In spite of a well-addressed point system the absence of a systematic evaluation framework restricts the opportunity to select the most optimised selection to claim the green star points. For instance, using green construction materials in a building is subjected to availability of the material otherwise points may be lost for not using locally available materials. Therefore, a consistent assessment platform is required for optimising the available green design options to promote effective green building decision making.

*Corresponding Author: E-mail – malindu.sandanayake@vu.edu.au

In most cases designers do not consider the practical limitations of certain construction technologies and resource usage which results in huge cost implications and unsustainable outputs. For example, use of prefabrication construction is found to be an effective and environmental friendly construction technique because of quick installation. However, studies have also highlighted transportation distance and longer waiting time may increase idle time and thus affect the construction time and environmental emissions (Sandanayake et al., 2017b; Frey et al., 2010). This also implies that sustainable decision of material usage or construction technique varies based on the types of project and other limitations. Often these complications are observed at later stages which results in reactive measures. Moreover, some of the environmental impact assessment platforms such as commercial LCA software requires complex modelling and expert opinions. Therefore, the requirement of a proactive comparison platform would really assist the decision makers to optimise their green decisions. Thus, the objective of the paper is to develop an evaluation framework using Building Information Modelling (BIM) that compliments the green star rating system and optimises the green designs and sustainable decision making for a building. The outcomes of the study is valuable for designers and contractors who are keen on achieving high environmental friendly construction without compromising the construction time and profit. A generic case study in Melbourne, Australia is used to demonstrate the functions and the capabilities of the framework.

2. LITERATURE REVIEW

Sustainability in building construction is defined as the use of building materials, techniques, equipment, and transport to minimize the economic, environmental and social impacts (Fowler & Rauch, 2006; Ding, 2008). However, the unique construction techniques and the site-specific limitations have been some of the major impediments in implementing sustainability at the construction stage. For example, it has restrained the current sustainability assessment tools by either ignoring or approximating the impacts during the construction stage of a building (Illankoon et al., 2017; Doan et al., 2017). The common challenge of minimization of economic impacts not complimenting the reduction of environmental and social impacts led the stakeholders to ignore sustainability aspects of building construction. With the pressure from government and public, the usually ignored aspects of sustainability should be back for consideration in the current construction design and implementation to maintain a healthy development environment with optimized economic benefits. For example, maintaining a balance between carbon emissions and construction cost without compromising the site-specific constraints from their construction activities is one of the objectives of next-generation development (Sandanayake et al., 2017a; Zhong et al., 2017; Fregonara et al., 2016).

In addition, many studies have attempted to quantify the environmental and economic benefits in building designs using various assessment models and techniques (Tsai et al., 2013; Doczy & AbdelRazig, 2017; Shen et al., 2007). Several input parameters such as GHG emissions, indoor air quality, and energy consumption have been considered with economics parameters to obtain the most sustainable design (Steinemann et al., 2017; Chen & Thomas Ng, 2016). Out of these, GHG emissions have been that major environmental parameter considered (Yan et al., 2010; Ji et al., 2017). This is majorly due to the overwhelming contribution of GHG emissions to the global warming potential. However, most of these studies have highlighted issues with data acquisition, management and usage issues associated with manual data handling (Zhang et al., 2017; Sandanayake et al., 2018b). Restrictions over comprehensive assessment was noted as the major limitation as a result of these issues. Building Information Modelling (BIM) has been identified as a potential tool that can eliminate these issues in manual data collection and management (Hardin & McCool, 2015; Zhong et al., 2017). BIM is a technique that also has the capacity to eliminate the potential silos in information management and thus promote the comprehensive sustainable assessment (Hardin & McCool, 2015; Cheng et al., 2016). The potential advantages of interoperability between the BIM model and decision making techniques can be exploited effectively to develop a platform that can acknowledge both green certification and sustainability aspects of a building (Li et al., 2017).

Environmental emissions of a building spreads over wide range along the life cycle starting from material extraction stage through to construction stage, maintenance and finally end-of-life cycle stage. A set of studies have concentrated on estimation of construction waste as means of assessment of environmental impacts of buildings (Li et al., 2014; Silva et al., 2014; Wu et al., 2016). The findings of the study emphasize the importance of recycling materials and the use of recycled materials in building construction. However, the major focus of building emission studies were on air emission calculations. This is due to the long life cycle and the huge energy consumptions. Majority of these air emission studies on buildings have emphasized the dominance of emissions at the use and maintenance phase overpowering the emissions at other life cycle stages. However majority of these studies have concentrated on estimating GHG emissions while giving less significance to other non-GHG air emissions (Mao et al., 2013; Sandanayake et al., 2018a; Aye et al., 2012). These studies have highlighted the 70-80% of use phase GHG emissions as compared to 4-12% construction stage emissions, 8 to 15% materials stage emissions and 3 to 5% end-of-life GHG emissions (Guggemos & Horvath, 2006; Guggemos, 2003).

Despite the lower life cycle contribution, Construction stage building emissions are associated with several emissions (Sandanayake et al., 2016a; Mao et al., 2013). These emissions can be GHG emissions and non-GHG emissions as a result of fossil fuel combustion. The importance of assessment of construction stage emissions and impacts are highlighted in a number of previous studies (Sandanayake et al., 2017b; Sandanayake et al., 2016b). These studies highlight the importance of assessing in-depth construction stage emissions because it leads to short-term and localised environmental impacts. Especially due to the direct emission release of non-GHG emissions as a result of fossil combustion, other environmental impacts such as acidification potential (AP), Photochemical Oxidation Formation Potential (POFP) and Human Toxicity Potential (HTP) can have major influence for the environment.

Therefore, it is important to investigate the possibilities of reducing the construction stage impacts without compromising the cost implications.

3. Development of Framework

Based on the literature review and initial consultation with green building professional a framework is established that can help the decision making process. The framework is developed in two major steps. Step one is to develop the BIM enabled data management framework which enhances the data management process for sustainability assessment.

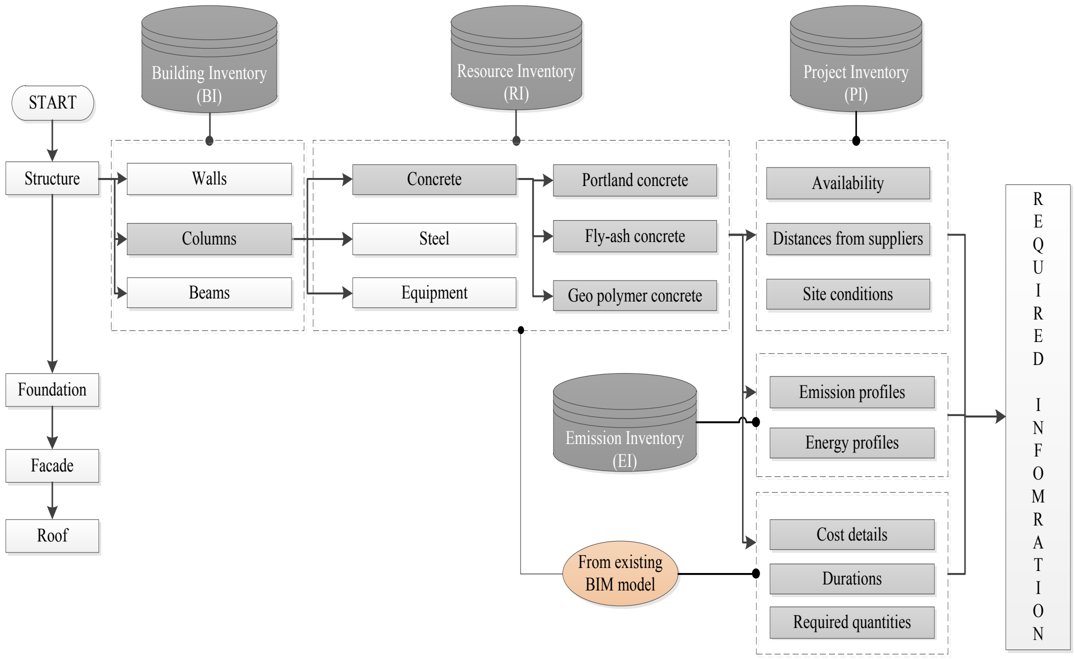

Figure 1: Information Flow in the Proposed BIM Enabled Data Management Framework

Step two is to divert the required information towards the optimisation assessment. Figure 2 highlights the decision-making framework proposed for decision making in green building design. However, the current study considers only the highlighted sections in Figure 2.

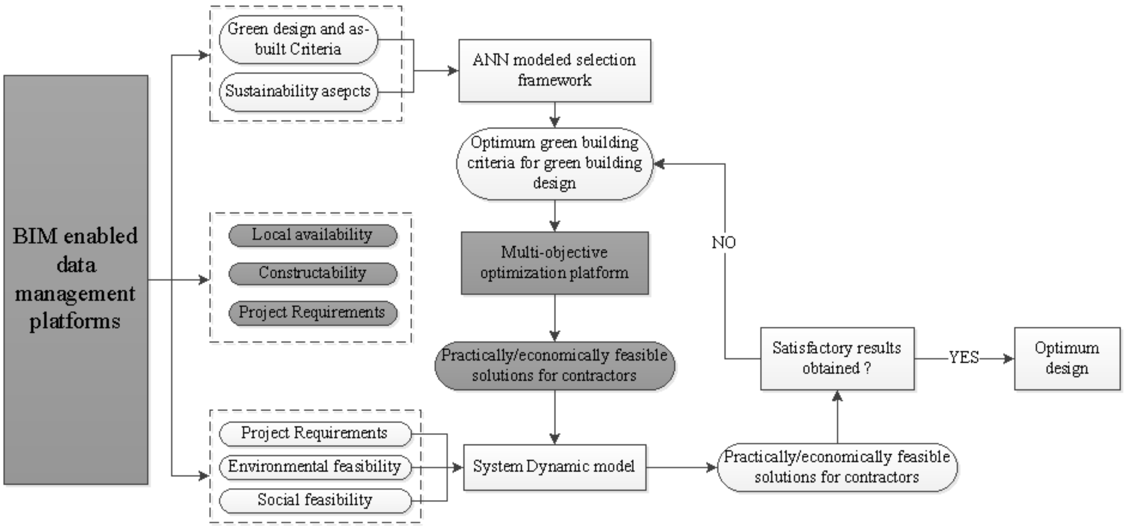

Figure 2: Integrated Decision-Making Framework

4. RESEARCH MODELS AND METHODOLOGY

4.1. *THE SCOPE AND SYSTEM BOUNDARY OF THE STUDY*

Majority of the sustainable building decisions are made during the conceptual stage of a building and often involves emissions and impacts of all life cycle stages of a building. While acknowledging the importance of considering all life cycle stages impacts in decision making, the current study aims to include the construction stage impacts in decision making of green building design. Air emission is the major emission type considered in the current study. Both GHG and non-GHG emissions are present in construction stage due to combustion of fossil fuel. CO_2 emissions are considered as GHG emissions because majority of the GHG emissions are CO_2 emissions especially with fossil fuel combustion. Therefore, GHG emission substances are chosen as they are the pre-dominant pollutant substances associated with fossil fuel combustion.

The most comprehensive system boundary for emissions and impacts at building construction should include embodied emissions from materials, emissions from equipment usage and transportation and emissions due to electricity consumption. These impacts can either be direct or indirect emissions based on the location and the severity. Even though there is a controversial opinion of including embodied emissions from materials in the construction stage, several studies have included it to maintain the inclusiveness of the analysis. Therefore the study considered three major emission substances including embodied emissions of materials (E_M), emissions due to machines and equipment usage (E_i) and emissions due to transportation ($E_{Ti,j}$). Emissions due to electricity usage is mainly due to equipment use and thus is included in E_i calculations.

LCA is the major methodology used for assessing environmental emissions and impacts of a building life cycle. Out of the three major LCA methodologies (Input-output, Process and Hybrid), process based quantitative approach is selected to assess the environmental impacts. This is because a lot of information for the case study was readily available and for a comparative assessment process-based models are found to be the most effective approach (Yan *et al.,* 2010; Mao *et al.,* 2013).

4.2. *EMISSION ESTIMATION MODELS*

Air emissions have been the major research consideration when building construction is considered. In general, total emissions (*TAE*) from building construction can be expressed as follows:

$$(TAE)_i = [\sum_{i=1}^{n}[(M\{\lambda, m\} + EQ\{t, f, \eta, p, \varepsilon\} + T\{d, f, \varepsilon\} + EL\{p, t, \eta\}] \quad \text{Eq. (01)}$$

Where, *M* is the emissions from materials; *EQ* is the emissions from equipment; *T* is the emissions from transportation and *EL* is the emissions from electricity for the i^{th} pollutant type.

Emissions from materials are obtained from the following equation (Mao *et al.*, 2013).

$$E_M = \sum Q_i * e_{im} \qquad \text{Eq. (02)}$$

Where, *EM* is the embodied emission of materials (*i*) used in the construction phase in kg of pollutant-eq, *Qi* is the amount of ith material used in kilograms and e_{im} is the energy factor or the emission factor for i^{th} material in kg-pollutant equivalent-eq/kg.

Emissions due to transportation are calculated using the equation below (Sandanayake *et al.,* 2017b).

$$ET_{i,j} = \frac{A_{i,j} * EF_{i,j}}{1000} \qquad \text{Eq. (03)}$$

Where: $ET_{i,j}$ is the ith emissions from the fuel type (j), $A_{i,j}$ is the activity type for calculating emission type i. For greenhouse gas emissions it is equivalent to the multiplication of quantity of fuel consumed in kL and energy content factor for fuel type (j) in GJ/kL and *EFj* is the emission factor for the fuel type (j) in kg-emissions/GJ. For non-GHG emissions the $A_{i,j}$ is calculated using characteristics such as the power of the machine (kW) and the deterioration of the vehicle and the cumulative distance travelled (km).

Similarly, emissions from construction equipment can be estimated as mentioned in the following equation (Sandanayake *et al.,* 2016a).

$$\mathrm{E_i} = EF_i * P * T * LF \qquad \text{Eq. (04)}$$

Where: EF_i is the emission factor for the emission element i considered in g/(kW-hr); *P* is the rated power output of the equipment considered in kW; *T* is the hours of use of the equipment for the activity considered; *LF* is the load factor which is the fraction of available power during the operation of equipment.

4.3. COST ESTIMATION MODEL

Total construction cost (*TCC*) including direct (*D*) and indirect (*I*) costs can be represented from the following generic equation.

$$TCC = [(MC)_D + (LC)_D + (EC)_D + (TC)_D + (GC)_I] \qquad \text{Eq. (05)}$$

Where, *MC* is material cost, *LC* is labour cost, *EC* is equipment cost, *TC* is transportation cost and *GC* is green cost.

4.4. BIM MODEL AND DATA EXTRACTION METHOD

A typical residential building located in Melbourne, Australia is used as the base case for the analysis. The floor area of the building is 231 square metres. The construction site was flat without any major excavations. The local environment of the construction site was observed suburban. The building consists of four bedrooms with a living room, family room, two bathrooms and a garage. The soil type was classified as class "H" based on the soil reactivity. Waffle pod slab was utilised as the foundation for the building. Using Revit BIM the 3D model is developed for the case study to obtain the necessary information for the optimisation assessment. Figure 3 and 4 illustrate the developed BIM model and the building plan of the case study used.

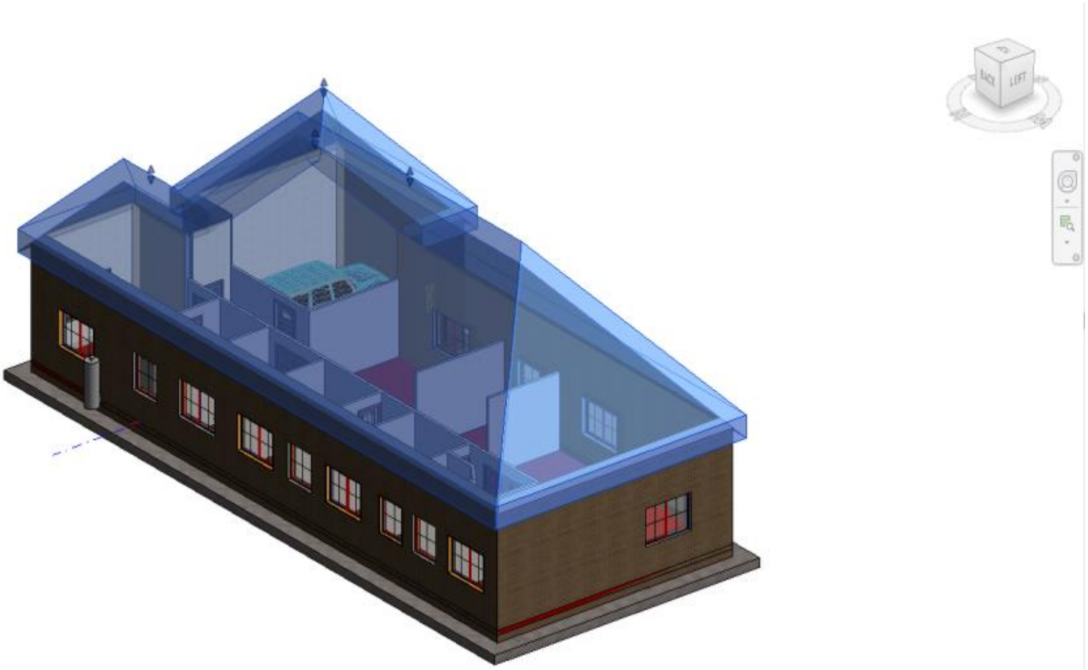

Figure 3: Modelled House Using Revit BIM

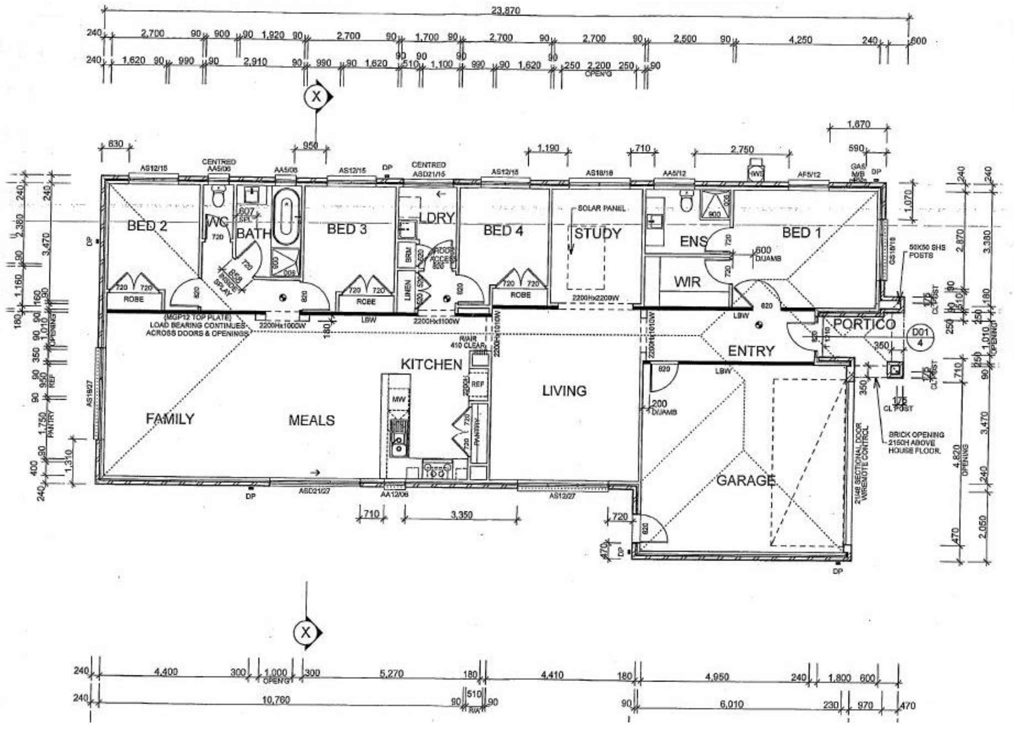

Figure 4: Building Plan Used for the Case Study

4.5. OPTIMISATION TECHNIQUE AND OBJECT FUNCTIONS USED

Precise modelling is required to incorporate the critical project parameters in these model components to increase the accuracy of the optimization process. For instance, using a locally unavailable sustainable material may reduce the material and green costs but the transportation and labour costs may be higher than the locally available material. Therefore, multi-objective optimisation based algorithm is developed to investigate cost and emission aspects of building construction.

The optimization algorithms and prototypes are based on multi-objective particle swarm optimization (PSO). PSO concept is developed by Kennedy and Eberhart (Kennedy *et al.*, 2001) based on the social behaviour of birds. The population of candidate solution is called a "swarm" and each individual in the space is called a "particle". The PSO procedure used in this research study is shown in Figure 5. The initial step is to identify the swarm objective function (Isus). The basic parameters for optimization such as environmental parameters, cost parameters and site specific parameters were then be obtained from site working sheets and from site management reports. The initially randomly generated solution for the object function is then evaluated in each step. With each iteration, the economic environmental parameters are assessed subjected to the local demands. The fitness of the swarm is then calculated to determine global best position for the particle. The objective functions and the relevant constraint functions are explained in the equations below.

Objective function:

Minimise, f_1 = *total air emissions (TAE)*

f2 = total construction cost (TCC)

Subjected to constraints:

Fly ash quantity (x), $0 \geq x \geq Qi/2$ ($Q_i = 118\ m^3$)

Slag concrete (y), $0 \geq y \geq Qi/2$

Recycled coarse aggregate (z), $0 \geq z \geq qi/2$ ($q_i = 94\ m^3$)

Recycled construction waste (ñ), $0 \geq ñ \geq (0.10)\ Qi/2$

The objective function is to minimise GHG emissions and construction cost explained in Eq. (01) and (02) for the considered design inputs described in the following section. 50% of green materials are used in the optimisation study because geo-polymer concrete should be off-site fabricated due to heat curing and thus foundation cannot be off-site fabricated. The beams, columns and wall panels are assumed to be off-site fabricated with green materials for Scenario 1 (SC1). In Scenario 2 (SC2) and Scenario 3 (SC3), 50% replacement of in-situ concrete and 50% recycled coarse aggregate is used respectively to maintain the uniformity of the analysis. However, in real case analysis this assumption is not necessary. Table illustrates the major details of the design scenarios considered for the study. In the study recycle of construction waste refers to concrete waste recycling.

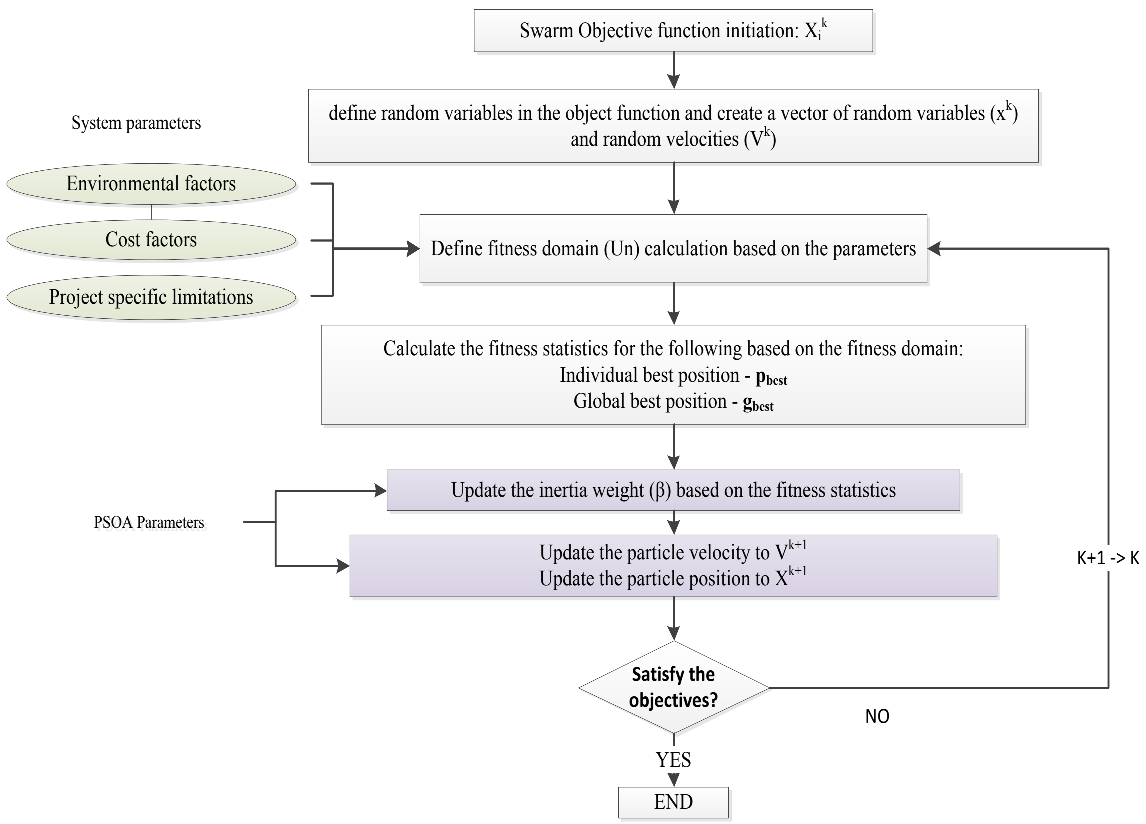

Figure 5: Flowchart for the Swarm Particle Optimization Procedure

Table 1: Design Inputs Considered for the Optimisation Study

Notation	Design input	Description
SC1	**Use of green materials – Option 1**	In this scenario 50% of in-site concrete is replaced with fly-ash Geopolymer concrete.
SC2	**Use of green materials – Option 2**	In this scenario 50% of in-situ concrete is replaced with slag concrete
SC3	**Use of recycled materials**	In this scenario 50% recycled coarse aggregate in concrete
SC4	**Recycling of construction waste***	The scenario considered 80% recycled construction waste for the case study

* (Sandanayake *et al.,* 2018a)

5. RESULTS AND DISCUSSIONS

The case study developed using Revit BIM is used to demonstrate the functions described in step 2 of the framework described in Section 3. Data and information from BIM model and other inventories have been used for the optimisation assessment. Since the BIM enabled data management platform is not developed the automation could not be demonstrated. For explanation purposes, the variation of GHG emissions with construction cost is discussed in the results section. Based on number of results obtained from the optimisation assessment eight discrete results were selected to demonstrate the significance of the results. The corresponding results of the optimisation assessment is shown in Table . The base case (reference) scenario observes GHG emissions of 54.8 tons-CO_2-eq while the construction cost is found to be $ 28,320. Seven major outputs with different combinations of scenarios show discrete reduction/increase GHG emissions and construction cost.

Table 2: GHG Emissions and Total Cost for Different Combinations

No	Combination				GHG emissions (tonsCO_2-eq)	% difference*	Total Cost ($)	% difference*
	SC1	SC2	SC3	SC4				
Ref	-	-	-	-	54.8	-	28,320	-
1	50%	-	-	-	47.51	- 13.3%	37,608.96	+ 32.80%
2	-	50%	-	-	44.23	- 18.2%	30,343.41	+ 7.14%
3	-	-	50%	-	52.12	- 4.89%	29,100	+ 2.75%
4	-	-	-	80%	53.1	- 3.10%	29,300.54	+ 3.5%
5	20%	20%	20%	80%	44.8	- 18.25%	29,458.95	+ 4.02%
6	35%	20%	50%	80%	42.4	- 22.60%	31,357.75	+ 10.73%
7	20%	43%	30%	63%	44.1	-19.52%	30,015.13	+ 6.0%

* (-) refers to a reduction and (+) indicates an increase

The comparative results indicates that scenario 2 (SC2) and scenario (SC3) provide the most optimum results when only one scenario is considered. As such SC3 provides 4.89% GHG emission reduction per 2.75% cost increase and SC2 provides an 18.2% GHG emission reduction with 7.14% cost increase. Thus, it further highlights that SC3 1.78% GHG reduction per unit cost increase while SC2 highlights 2.55% GHG reduction per unit of increase. However, the important notice here is that none of the options provides a cost decrease. This is because all the green/sustainable design options carry an additional cost as compared to traditional designs.

The results in the table also highlight various combinations that provides GHG emission reduction. Out of three combinations, set 5 with 20% from SC1, SC2, SC3 and 80% from SC4 provides an 18.25% GHG emission reduction per 4.02% cost increase which gives a 4.54% GHG reduction per unit cost increase. This is also the best obtained result among all the combinations considered. The results further justify the importance of having an integrated decision making framework that provides the most optimum design for minimising emissions with minimum cost implications. A similar analysis can be conducted for other pollutant substances and thus final decisions can be made based on the priority and the requirements of the green design submission.

6. CONCLUSIONS AND FURTHER RESEARCH

Green rating is a popular benchmark to evaluate the environmental friendliness of a building. However, with the lack of acknowledgement between the environmental emissions and construction cost the contractors are faced with the dilemma for optimised decision making. With the increased cost and lack of availability of some of the green materials there is a contemporary requirement for decision makers to optimise the available options that minimise both cost and emissions without compromising the project limitations.

Therefore, the study considered four different material options to investigate the emissions and cost variations to select the optimised selection for green building design. Four design options involving use of green materials (SC1 and SC2), use of recycled material (SC3) and recycling construction waste (SC4) are considered for the optimisation study. The results indicated that a combination of various design options provide the most optimum output. Observations from the analysis highlighted a maximum of 4.54% GHG emission reduction per unit cost increase using combination of different scenarios as compared to a maximum of 2.55% GHG emission reduction per unit cost increase considering only one scenario. However, these results are case study specific and could vary for different building case studies based on project specification factors material availability, transportation distances and site location. The results obtained in the analysis further justify the importance of optimisation between various designs prior finalising the design for green/sustainable building construction.

The paper presented an initial analysis of using BIM and optimisation techniques to upgrade the green building decision making process. The authors are in the process of developing a BIM enabled sustainable decision making platform that promotes the green building submission processes. The current study used the BIM generated input design information to manually conduct the optimisation assessment for sustainability assessment. However, once developed, the full decision making platform will enable automated decision making to improve the material selection, construction technique, resource management at building site and waste minimisation to obtain the optimum green rating points.

The current study only considered construction cost in cost optimisation model. Moreover, only material specific design options were considered for the optimisation study. The optimisation study also didn’t consider any project specific constraints or limitations. The research team is planning to include all the life cycle stages of a building into the decision making platform to upgrade the decision making process. Future studies are also encouraged on conducting comprehensive assessment including the life cycle cost, project specific limitations to discover several design aspects in green building design and submission.

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BROWNFIELD REDEVELOPMENT: A DUAL CURRENCY ANALYSIS OF SOIL STABILISATION METHODS

Lee Brown[1], Srinath Perera[2*] and M.N.N. Rodrigo[2]

[1]Architecture and Built Environment, Northumbria University, United Kingdom

[2]School of Computing, Engineering and Mathematics, Western Sydney University, Australia

ABSTRACT

Evidence of climate change, such as rising sea levels and higher average temperatures, has made society become increasingly carbon conscious in recent years. Therefore, carbon estimating is becoming prominent and this research explores methods of quantifying embodied carbon of different soil stabilisation methods. This research aims at evaluating the different methods of soil stabilisation for the remediation of previously developed, brownfield sites, using a dual currency approach of investigating both cost and carbon. Therefore, the effect of using different cementitious binders such as Pulverised Fuel Ash (PFA) and Ground Granulated Blastfurnace Slag (GGBS), in lieu of Ordinary Portland Cement (OPC) was investigated.

Primary data, in the form of Bills of Quantities, was collected from a civil engineering contractor who has extensive experience in the land remediation sector in the UK. This enabled cost and carbon rates to be applied to the work items, to estimate in terms of cost and carbon inputs. This data was analysed using descriptive statistics to investigate if there is a correlation between cost and carbon inputs.

The study revealed that to stabilise soil, soil matrix changes from one binder to another, whereas a higher content of GGBS and PFA to lime in the alternative methods than there is for OPC. In lieu of OPC and PFA, GGBS was identified as the most cost effective and lowest carbon emitting cementitious binder. However, though PFA also signified a carbon saving, PFA was comparatively costly. Further, a perfectly positive correlation lies between the mean elemental unit rates for costs and carbon.

Keywords: *Cementitious Binders; Correlation; Embodied Carbon; Soil Stabilisation.*

1. INTRODUCTION

Due to increasing environmental concerns surrounding the development of greenfield sites, the UK government has stated that at least 60% of new housing developments must be on previously developed 'brownfield' land, much of which contains soil contaminants stemming from their previous uses. Traditionally, the approach was to excavate the contaminated soil and dispose at landfill (The Concrete Centre, 2005). Excavation and disposal to landfill is an important means of managing contaminated land. It can offer a 'complete solution' on the proviso that all contaminants with unacceptable risks are removed from site. However, there are numerous disadvantages, including but not limited to the following; hazards and nuisance related with the transport to landfill, noise, gases and dust arising from the excavation and the rising costs associated with the disposal at landfill (landfill taxes and the likes). There are many contamination and operations related hazards associated with 'dig and dump' with operatives working in close proximity with contaminated materials and where unstable conditions are present (CIRIA, 1995). A combination of these factors drives the search for safer, more sustainable methods of remediation.

Issues arising from the EU Landfill Directive in 1999, namely the prohibition of the co-disposal of inert and hazardous waste and subsequently the reduction of available landfill sites, led to increasing costs associated

*Corresponding Author: E-mail – Srinath.Perera@westernsydney.edu.au

with the preferred "dig and dump" method of remediation. As a result, solidification/stabilisation has become a more cost-effective and sustainable approach to remediating brownfield sites.

After the advent of remediation processes in the 1970's, due to high public demand, energy-intensive engineering technologies were adopted for "quick clean-ups" of contaminated land. More recent evidence of a correlation between energy consumption and climate change has led to society, and therefore remediation professionals, to seek ways of minimizing the reliance on technologies that have a detrimental impact to the environment (Ellis and Hadley, 2009). Traditionally the management of contaminated land has been concerned with mitigating the risk posed to human health and to the environment; however, incorporating the sustainability factor into decision making and project planning is becoming more customary. Within the UK economy, the contaminated land industry is worth in the region of £1 billion so sustainability is an important issue for debate. A sustainable remediation project should aim to achieve a net benefit overall across the three main pillars of sustainability; social, economic and environmental factors. Unfortunately, measuring sustainability proves rather difficult as it is a subjective concept that is not easily quantifiable. There exists a need to compare sustainable remediation technologies and monitor remediation performance as opposed to direct measurement (Bardos, 2014). The 2009 Sustainable Remediation Forum (SURF) White Paper explains that there is a requirement for identifying a "unit of remediation" in order to be able to carry out these site versus site comparisons but at the time of that publication going to press nothing had yet been agreed upon. SURF concurs that resolving the issue of how best to define a unit of remediation would enable the industry to make better decisions regarding sustainability (SURF, 2009).

The works of Victoria et al. (2015) along with Victoria et al. (2016) had carried out an investigation into Embodied Carbon (EC) in commercial office buildings, and the findings have been used to produce a carbon profile. However, there is a dearth of knowledge relating to the earthworks operations carried out on construction projects, in terms of EC. This research seeks to bridge that knowledge gap.

The aim of this research is to evaluate different methods of soil stabilisation for the remediation of previously developed, brownfield sites, using a dual currency approach of investigating both cost and carbon. The research seeks to identify a less carbon intensive, more environmentally friendly method of ground remediation than using cement and lime. In order to achieve the aim, the objectives of the research are as follows:

- To critically appraise different soil stabilisation techniques using different cementitious binders
- To analyse the cost and carbon implications of the various stabilisation procedures
- To establish a carbon profile for the remediation of brownfield sites

2. LITERATURE REVIEW

2.1. SOIL STABILISATION

Soil Stabilisation (SS) also known as soil solidification is a civil engineering technique used to improve the condition of soils, either in the remediation of contaminated land or by improving the load bearing capacity of the soil. This type of ground improvement engineering utilises a reaction between binders in the solidification reagent, such as cement/lime and the contaminants present in the soil to provide stabilisation, reducing the mobility of the pollutants. Stabilisation is attained by adding reagents to contaminated soil, hence producing elements that are more chemically stable. Solidification is the process whereby the addition of these reagents imparts more physically stable properties, containing the contaminants in a solid and providing protecting from the ingress of air, water and other external agents (Environment Agency, 2004).

SS is a versatile technique working well with almost any type of contaminant. Its most effective use is in the treatment of metals but is also adept at treating inorganic and organic contaminants. This particular method of remediation is always designed with the project specific in mind, and varies from project to project. Scientific testing is used to verify the binder to be used and its composition, whereas treatability studies are employed to ascertain if the various needs of each project stakeholder are going to be met. The key stages in the design of a suitable remediation strategy are as follows. Firstly, samples are obtained from site of best and worst case scenarios, the engineering properties and the extent of contamination are then determined. This enables a suitable pre-treatment to be selected (if necessary) and appropriate binders and additives to be chosen. In the laboratory a sample remediation is conducted enabling the mix to be optimised in the most cost effective manner. Finally, field trials are carried out and a suitable remediation design is agreed upon prior to implementation (Angel, 2004).

Depending on various factors such as ground conditions, nature of contaminants, future use of site and access restraints, two SS methods are available; in-situ and ex-situ.

In-situ SS is the process where the contaminated soil is treated as it remains in the ground, in other words, it is not excavated. The specific technique of in-situ SS to be used is reliant upon the depth of ground to be remediated. If the required depth is deemed to be shallow (<0.5m) then the binder is spread across the surface of the area to be treated and mixed into the contaminated soil using a rotavator, it is then compacted and the reaction with the moisture content of the soil takes place. If the depth is intermediate (0.5-5m), then the binder is mixed into the soil using specially adapted plant. Any depth over 5m is classed as 'deep' and the binder is added to the contaminated soil using hollow stem augers, which when they withdraw mix the binder with the soil, the design allows for the augers to overlap ensuring the required coverage is attained.

Ex-situ SS takes place at the contaminated site and is the procedure where the polluted soil is excavated and stored in temporary stockpiles before being treated. There are various types of ex situ treatment. The excavated material can be mixed with the SS binder and laid in layers where it is required, this treated soil mix is then rotovated and compacted before the reaction between the binders and the soil moisture content takes place. Alternatively, the excavated material can be mixed in a drum with the appropriate reagent, where the required chemical reaction occurs, before being laid in layers and compacted. Another option is batch mixing, where the contaminated soil and the reagents are mixed in special purpose plant and left for a pre-determined time period, before the soil is laid and the reaction between the reagents and the soil moisture takes place. Ex-situ SS is particularly suitable for projects where there are buried obstructions or where the remediated soil is usable as engineered fill (The Concrete Centre, 2005).

2.2. CEMENTITIOUS BINDERS

The mixture of additives and elements used in the stabilisation procedure is known as the binder. A binder can either be a single component or a combination of various reagents, or multi-component binder. Each remediation site differs from the next in terms of the type of contaminant to be dealt with, the make-up of the soil and the remedial objectives. As such the binder selection is influenced by scientific tests conducted in laboratories along with previous experience, and is specific to the contaminant being treated (Angel, 2004).

The main binders used in this research are Ordinary Portland Cement (OPC), Pulverised Fuel Ash (PFA) and Ground Granulated Blastfurnace Slag (GGBS).

Ordinary Portland Cement

Due to its use in the manufacturing of concrete, cement is one of the most commonly used building materials worldwide. The benefits of using cement are that it is durable, versatile and provides great economic value. It is readily available and is manufactured using local products, transport related energy and pollution costs are kept to a minimum (Juenger et al., 2011). However, there are many drawbacks to the use of OPC. The cement manufacturing process requires the input of many raw materials. As such, cement plants have traditionally emitted large amounts of solid waste and waste particulates, hence having a detrimental effect on the environment (Sabnis and Carter, 2011). Hammond and Jones (2011) in the Inventory of Carbon and Energy (ICE) have approximated the EC content of Portland cement at 0.93kg/CO_2 per kilogram, signifying that it has an extremely carbon intensive production process. This leads the quest for environmentally friendly alternatives like, as mentioned above, PFA and GGBS.

Pulverised Fuel Ash

Pulverised Fuel Ash, or fly ash, is produced by burning coal in power stations. The molten ash drips to the bottom of the furnace creating 'furnace bottom ash', or when carried via convection with the gas stream, fly ash. This unprocessed material can be used in the production of cement and concrete or further refined by the use of classifiers into a finer ash. As this material is a by-product of coal burning power stations the EC content is lower and is a greener alternative to Ordinary Portland Cement. It has an EC content of 0.008kg/CO_2 (Hammond and Jones, 2011).

Ground Granulated Blastfurnace Slag (GGBS)

Ground granulated blastfurnace slag is the by-product of the steel manufacturing process. In this process, the iron ore is converted into iron and the excess materials float on top of the molten iron as slag. This slag is then subjected to large volumes of water to convert it into coarse granules, which are then ground to produce GGBS. Due to being a by-product created in the manufacture of steel it is considered to be a more environmentally friendly cementitious binder (Concrete Society, 2011). GGBS is listed in the ICE as having an EC content of 0.083kg/CO2 (Hammond and Jones, 2011).

2.3. CARBON ESTIMATING AND PROFILING

Embodied carbon/energy

Embodied energy is defined by Hammond and Jones (2008) as the total primary energy consumed by a building material over its life cycle. 90% of this carbon released is apportioned to 'operational energy' with the remainder labelled embodied energy, or the total energy expended to create the building fabric, from raw materials to disposal (Goggins et al., 2010). This description is emphasised by the Hammond and Jones (2008) which pronounces that embodied energy should include the carbon emitted in the building material manufacturing process, the energy and emissions associated with transporting the goods to site, assembly, refurbishment, replacement and demolition or disposal at the end of the life cycle. As regulations are introduced to reduce the operational carbon emissions in order to achieve the 2050 targets, the spotlight will fall more on the embodied energy of a building (WRAP, 2011). This is also brought to light in the Low Carbon Construction Final Report (Morell, 2010).

Embodied Carbon (EC) estimating

The embodied impact of a building material on the environment is measured as EC, in main due to the increasing awareness of the correlation between energy emissions and climate change. The total EC of a product can then be calculated by assessing the energy expended in the production of the material and adding in the CO_2 emissions from that process (Hammond and Jones, 2008). EC measurement is a branch of a process called Life Cycle Assessment, which is used by construction material manufacturers for the production of robust environmental data about their products, primarily concerning emissions (Anon, 2016). Dixit et al. (2010) observed that there are three boundaries to which embodied energy can be attributed: cradle to gate, cradle to site and cradle to grave. Although the Institution of Civil Engineers definition above points towards a cradle to grave analysis for EC, the Inventory of Carbon and Energy suggests that this should be subdivided into sections, as transport "from gate to site" accounts for less than 7% of the cradle to site EC (Hammond and Jones, 2011). More recent research conducted by Victoria et al. (2016) identified further system boundaries in the form of cradle to end of construction and cradle to cradle (which accounts for recycling of materials at the end of their life cycle).

As of yet, there are no published regulations for the assessment of EC, making the implementation of carbon reduction policies somewhat difficult. Recommendation 2.1 of the Low Carbon Construction Final Report states that as soon as a robust system of carbon assessment is available then the requirement to conduct a Whole Life carbon appraisal should be implemented into the Green Book (Morell, 2010). As there is an absence of an industry standard for accurately measuring Embodied CO2 there are many different models in existence. The Building Research Establishment has established "envest2", a software tool that predicts the environmental impact of a project (Envest, 2016); The RICS has published "Redefining Zero" which estimates the EC at each stage of the RIBA Plan of Work, from cradle to grave (Sturgis and Roberts, 2010) and there also exist carbon calculators from the Carbon Trust and Cap2 IT.

Geoffrey Hammond and Craig Jones of Bath University's Sustainable Energy Research Team have produced a database of embodied energy and carbon of construction materials; this is published by BSRIA, a construction research body. This database is the Inventory of Carbon and Energy (ICE) and according to al Philip Lee of the Select Committee for Climate Change, highlights the difficulties encountered in assessing carbon. Hammond and Jones (2011) state that although there is in existence, a number of similar inventories available, the ICE is well established and recognised industry wide. Other reputable methods of measuring EC include the Civil Engineering Standard Method of Measurement 4 (CESMM4), the RICS' New Rules of Measurement 3 (NRM3) and the UK Building Blackbook. The Institution of Structural Engineers is also publishing an EC guide for its members (Hammond and Jones, 2011).

Carbon profiling

In the United Kingdom, construction legislation traditionally concentrated on the operational carbon emissions from a building when the whole life cycle carbon emissions were being quantified. The industry was all too keen to disregard or ignore the relationship between operational and embodied carbon. In the RICS research paper "Redefining Zero", Sturgis and Roberts (2010) state that the quantity of carbon used to create and maintain a building is significant, and by simply disregarding its importance, environmental and financial resources have been misallocated. In order for the UK to fulfil its commitments to the Kyoto Protocol of reducing greenhouse gases by 80% by 2050 (HM Government, 2008), the UK implemented various legislations and regulations in order to reduce the operation carbon emissions of buildings. The problem being the lack of legislation governing EC in projects, which can reach levels as high as 62% of a buildings whole life carbon emissions. The main problem identified by Sturgis and Roberts was that there was no identifiable standard method for measuring whole life carbon in buildings. Their proposal was a simple carbon metric known as Carbon Profiling be used to quantify all carbon emissions. This method considers the operational and embodied carbon of a project together, enabling a better allocation of the aforementioned resources (Sturgis and Roberts, 2010).

Under their proposed new metric of Carbon Profiling, work items are grouped into elements in order to analyse the EC content for each section of the works. The fundamental objective of this metric is to analyse both operational and embodied carbon over the same time and crucially, in the same units of measurement (Sturgis and Roberts, 2010). Part L of the Building regulations requires that a Building Emission Rate (BER) is calculated, this is the operational carbon cost of the construction project, in other words the carbon emissions associated with the building in operation. Using the same unit of measurement (kg/CO_2) carbon profiling estimates the EC efficiency of a building, by analysing each component in turn (Hartmann, 2009).

In this research the carbon profile will be compiled as follows; site clearance, excavation, disposal, breaking out obstructions, filling (including stabilisation with different cementitious binders) and compaction and surface finishes. A calculation will be carried out to find the elemental total cost and elemental carbon score for each. Once these totals are known, they will be divided by the site area in order to produce an Elemental Unit Rate (EUR) for both cost and carbon, measured in pounds (£) and kg/CO_2 per m^2. This enables to identify the more cost and carbon intensive elements present in the study.

3. METHODOLOGY

3.1. UNITS OF DATA MEASURE

The research considers a single case study by selecting a civil engineering contractor and within the case study, approximately thirty sites in which SS techniques have been employed, were selected as the principal data set for the research. Hence, the results are subjective to the single case study. A cradle to end of construction system boundary was implemented in the data collection. The raw data were developed with the application of cost and carbon rates to each item of work in order to estimate a project total in pounds and also a carbon score (kg/CO_2) for each. Secondary data in the form of the UK Building Blackbook (2011), CESMM4 Carbon and Price book and the Inventory of Carbon and Energy, were used for the dual currency rates. The Inventory of Carbon and Energy was used to provide carbon rates for soil stabilised with OPC, PFA and GGBS.

Unpublished Rates

The UK Building Blackbook (2011) does not contain all the information required to complete the study to a satisfactory level. For the contractor's stabilisation techniques employed throughout the study, the financial rates were obtained from the Civil Engineering contractor directly. The ICE publishes the EC content of stabilised soils in kilograms only. For the purposes of this research it is required that the rates be converted into m^3. This was done by taking the published rate in kilograms, converting into tonnes by multiplying by 1000 and then converting from tonnes into cubic metres (Hammond and Jones, 2011). This last step of the conversion is done by dividing the tonnage by a bulking factor of 2.1 tonnes/m^3. This is a figure widely used in the earthworks industry as a bulking factor for soil and Arup who have used a figure of 2.09 tonnes/m^3 on some of their sites (Arup, 2015) corroborates this. The tabulated results for carbon rates to be used in the data collection can be seen in Table 1.

Table 1: Conversion from kg to m^3 for Stabilised Soils

Material	$kgCO_2/kg$	$kgCO_2/tonne$	$kgCO_2/m^3$	Comments
Portland Cement (100%)	0.93	930	442.86	
General soil (rammed)	0.023	23	10.95	
5% cement stabilised soil	0.06	60	**28.57**	
GGBS stabilised soil	0.045	45	**21.43**	8% GGBS / 2% lime
PFA stabilised soil	0.039	39	**18.57**	8% PFA / 2% lime

In order to work out rates for soil stabilised with PFA and GGBS a simple calculation is required. The material specification for cement and lime is 3.5% cement and 1.5% lime, with the percentages in relation to the quantity of soil stabilised. It is assumed that a tonne of stabilised material would contain 35kg of cement; this is divided by the bulking factor (2.1tonnes/m^3) to specify a cement content of 16.67kg in every m^3 of stabilised soil. From the tonne rate for cement taken from CESMM4 Carbon and Price book (2013) a rate per kilogram of cement has been calculated. When this is applied to the quantity of cement above and the total subtracted from the cement and lime rate the 'base rate' for labour, plant and lime can be obtained. This same process will then be used to calculate the cost of substituting cement for the alternative binders, PFA and GGBS. These calculations are tabulated in Tables 2 and 3.

Table 2: Calculation of Stabilisation 'Base Rate'

Soil stabilisation material	Rate (£/m^3)	Binder	kg/t	kg/m^3	Rate per kg	Base rate less 3.5% cement
Cement/lime	£18.00	3.5% cement	35	16.67	£0.16	£15.33

Table 3: Calculation of binder rates

Soil stabilisation material	Binder	kg/t	kg/m^3	Rate per kg	Rate (£/m^3)	Base Rate
PFA stabilised soil	8% PFA	80	38.10	£0.22	£23.58	*£216.63/t
GGBS stabilised soil	8% GGBS	80	38.10	£0.06	£17.77	*£64/t

Correlation Co-efficient

The researcher will attempt to prove the existence of a correlation between cost per m^2 and carbon score per m^2. In order to carry out this investigation a correlation coefficient will be calculated. This co-efficient takes the form of a number between -1 and +1, with +1 being a perfectly positive relationship and -1 being perfectly negative (Witte and Witte, 2010).

4. APPLICATION OF PRIMARY DATA

To enable the researcher to meet the aim and objectives of this study, primary and secondary data was collected and processed to produce results. The collected data relates to cost in pounds and carbon measured in kg/CO_2. The purpose of this section is to analyse the collected data by utilising descriptive statistics and statistical testing, as outlined in Section 3.

4.1. CARBON PROFILING

The primary data was collected by the application of cost and carbon rates to items of work in each Bill of Quantities. This enabled the researcher to calculate totals for each project in relation to cost (£) and carbon score (kg/CO_2) for each soil stabilisation technique.

Filling with Cement/Lime

The unadjusted mean elemental unit cost is £15.72/m^2 with a standard deviation of £11.82. The process of statistically analysing each element identified extreme values which were disregarded before the calculation of descriptive statistics took place. Hence, the adjusted mean EUR was calculated to be £12.94 with a standard deviation of £4.99. This informs the researcher that the data points lie close to the mean and could be accepted as being representative of the whole population.

The unadjusted mean elemental carbon rate is 17.128 kg/CO_2 and the standard deviation is 14.326 kg/CO_2. The adjusted mean value EUR is shown to be 13.754 kg/CO_2 with a standard deviation of 7.063 kg/CO_2. The rather large deviation from the mean suggests that this mean EUR for carbon is representative of the sample only.

Pulverised Fuel Ash Filling

The unadjusted mean elemental unit cost is £15.84/m^2 with a standard deviation of £11.89. Removing anomalies in the dataset adjusts the mean value to £13.05 with a standard deviation of £5.03. As the data points lie close to the mean, this rate can be deemed to representative of the population.

The unadjusted mean elemental unit carbon rate is shown as 14.550 kg/CO_2 with a standard deviation of 12.697 kg/CO_2. The adjusted mean value is 11.558 kg/CO_2 with a standard deviation of 5.968 kg/CO_2. This dispersion away from the mean proposes that these figures are only representative of the sample projects.

Ground Granulated Blastfurnace Slag Filling

The unadjusted mean value elemental unit rate is £15.02/m^2 and the standard deviation was shown to be £11.99. These figures are adjusted to £12.24 and £5.33 respectively. This signifies that as the data lies close to the mean value then it can be accepted as representative of the population.

The unadjusted mean elemental unit rate for carbon was calculated as 14.706 kg/CO_2 and the standard deviation shown to be 13.450 kg/CO_2. The adjusted mean EUR for carbon is 11.560 kg/CO_2 with a standard deviation of 6.615 kg/CO_2. These figures will be deemed representative of the sample only due to large dispersion from the mean average.

The large standard deviations in this filling element can be attributed mainly to the range of quantities of filling across the sites used in the sample. The unit carbon rates for some of the sub elements are quite high meaning that whenever these activities take place in large quantities on some sites the elemental carbon score is affected, hence affecting the mean and standard deviation of the data.

4.2. COMPARISON OF ALTERNATIVE BINDERS

In order to achieve the aim of the research a comparison must be investigated between the ‘original’ soil stabilisation method of cement and lime and the alternative binders proposed by the researcher. The information for comparison is included in Table 4.

Table 4: Comparison of Different Cementitious Binders

Element	Binder	EUR (£)		EUR Carbon (kg/CO_2)	
		Mean	Standard Deviation	Mean	Standard Deviation
Filling	Cement/lime	£12.94	£4.99	13.754	7.063
	PFA	£13.05	£5.03	11.558	5.968
	GGBS	£12.24	£5.33	11.560	6.615

Replacing Cement with Pulverised Fuel Ash (PFA)

When substituting cement for PFA in the soil stabilisation method, as can be seen in table 3, the mean average EUR cost increases from £12.94 to £13.05. However, this change in cementitious binder brings forth a reduction in embodied carbon of 2.196 kg/CO_2 per square metre of treated land.

These results seem to suggest that the use of PFA as an alternative binder would result in a slight increase in project costs but would offer a significant carbon reduction, so would be a worthwhile consideration for the decision makers.

Replacing Cement with GGBS

The mean average elemental unit rate for the GGBS method is £12.24/m^2, a decrease in cost from the original rate of £12.94. The difference in mean elemental unit rate due to this binder replacement is therefore £0.70/m^2. The mean elemental unit rate reduces by 2.194 kg/CO_2. These figures demonstrate that replacing cement with

GGBS in the stabilisation technique offers significant reductions in terms of both cost and carbon. It would therefore be beneficial for the prudent contractor to consider this material substitution.

4.3. CORRELATION

By analysing all of the above cost and carbon rates, it appears that the expensive work elements are also the most carbon intensive. It could be proposed that there is a correlation between cost and carbon, more specifically it could be deduced that as cost increases so does carbon, indicating a positive correlation between the two variables. This can be seen in the following cluster chart (see Figure 1).

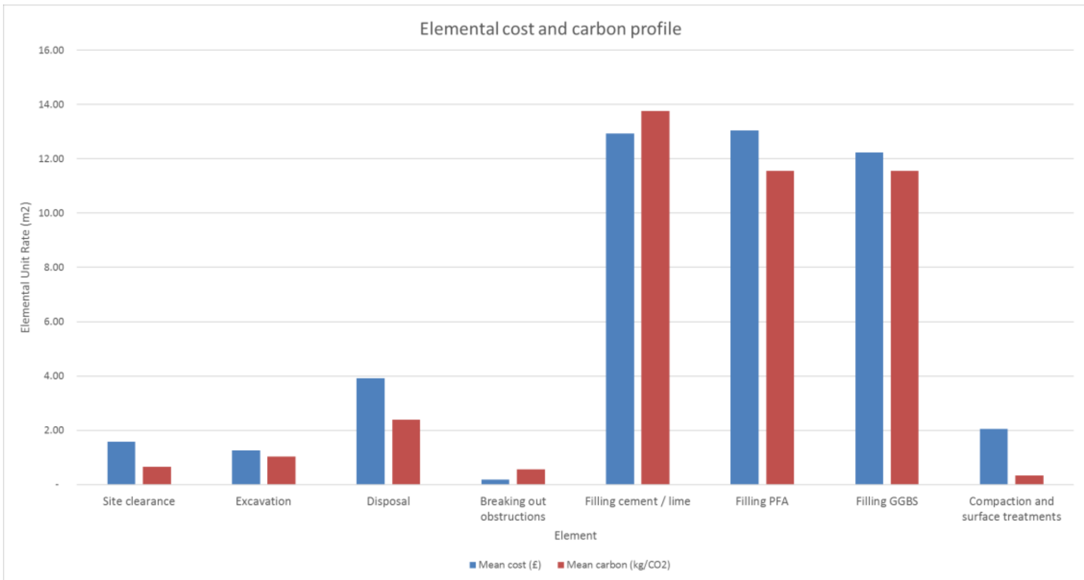

Figure 1: Elemental Comparison of Cost and Carbon

This hypothesis was tested using the correlation function on Microsoft Excel to compare the mean elemental unit rates of cost and carbon and calculate the correlation co-efficient, as outlined in Chapter 3. The results are as given in Table 5.

Table 5: Correlation between Cost and Carbon

Element	Binder	EUR (£) Mean	EUR Carbon (kg/CO_2) Mean
Site clearance		£1.58	0.654
Excavation		£1.25	1.032
Disposal		£3.92	2.388
Breaking out obstructions		£0.18	0.553
Filling	Cement/lime	£12.94	13.754
	PFA	£13.05	11.558
	GGBS	£12.24	11.560
Compaction and surface treatments		£2.05	0.328
Correlation co-efficient		**0.99**	

It can clearly be seen that, by comparing the elemental unit rates for costs with those for carbon, as the mean cost increases from element to element, so does the mean rate for carbon.

The correlation co-efficient was calculated as 0.99. A perfectly positive correlation between two sets of variables has a coefficient of +1. This leads the researcher to infer that there is a strong positive correlation between the mean elemental unit rates for cost and carbon. Element cost increases as the quantity of work in that element increases. On civil engineering sites this translates as more excavation work, more filling, more plant movements and in general more carbon intensive activities taking place. This correlation is better described in the illustration overleaf.

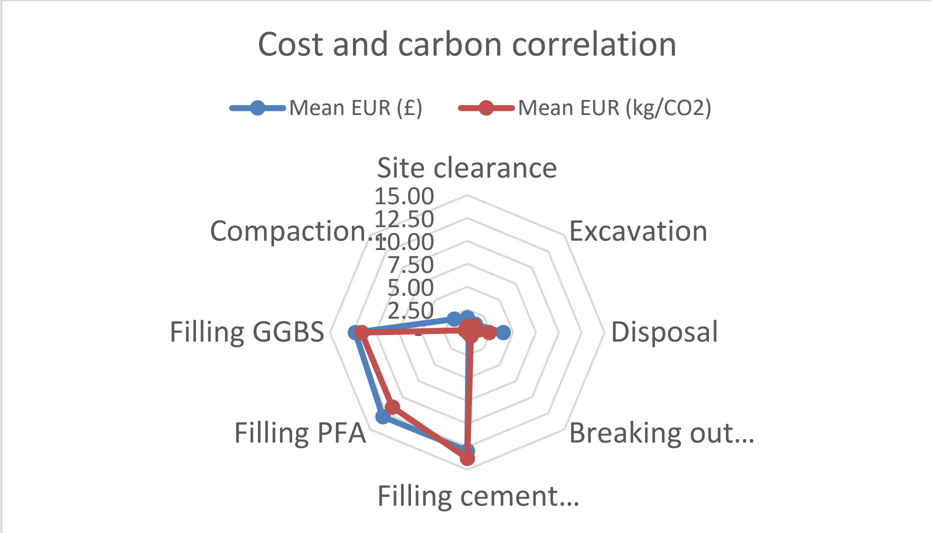

Figure 2: Elemental Correlation between Cost and Carbon

5. Conclusions

The principal aim of this research was to evaluate different methods of soil stabilisation for the remediation of previously developed, brownfield sites, using a dual currency approach of investigating both cost and carbon. In order to achieve the first objective; to critically appraise different soil stabilisation techniques using different cementitious binders, initially, in the data collection, the researcher gained knowledge on the chemical composition of the various binders and soil stabilisation mixes to be employed in the study. From analysing the secondary data, namely the ICE, it was evident that in order to stabilise soil, the soil matrix changes from one binder to another. There is for example, a higher content of GGBS and PFA to lime in the alternative methods than there is for OPC.

Subsequently, the second objective was to analyse the cost and carbon implications of the various stabilisation procedures was achieved. The published data highlighted that there were different EC values for the various cementitious binders. The expectation before conducting the study was that removing the more carbon intensive Portland Cement and replacing with more environmentally sustainable options would mean the contractor would incur an increase in material costs but would benefit from the carbon savings. The data analysis produced different results. It was discovered through the detailed analysis of results in relation to the elemental data that in replacing cement with PFA the costs did, as expected increased, albeit slightly, and the expectations in regard to carbon savings were realised. However, it was found that when GGBS was the alternative binder used in stabilisation costs actually dropped and the carbon reduction was even greater than with PFA.

The Hutchins UK Building Black Book (2010) provided costs and carbon rates for work items included in the primary data. These rates were applied to the work items and elemental totals for each project were obtained. The process of statistically analysing each element, as discussed in section 4, identified extreme values which were disregarded before the calculation of descriptive statistics took place. The mean averages and standard deviations were calculated and the carbon profile depicting cost and carbon rates on an elemental basis was produced to represent the sites in the case study. A perfectly positive correlation lies between the mean elemental unit rates for costs and carbon.

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BUSINESS MODEL CONCEPT FOR CONSTRUCTION BUSINESSES: A LITERATURE SYNTHESIS

D.N. Abeynayake*, B.A.K.S. Perera and Chandanie Hadiwattege

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Despite the importance of a business model (BM) to an organisation's success, clearing up the fuzziness of the concept of BM before applying it to any business or sector is worthwhile. Since definitions are expected to bring clarity, this paper attempts to analyse various definitions given to BM by different authors. Accordingly, eight notions around which 31 definitions of BM have been centred were identified. These notions are based on stakeholders, value, revenue, strategies, process, causality, elements and dynamicity of the business with which all the BM definitional views are associated. In addition to its two key roles, value creation and value capture, BM plays several other roles as well. Some of these roles relate to being an opportunity facilitator; a common language; a source of industry change; a source of competitive advantage and an exemplar. The paper also distinguishes the term BM from the other commonly used term in the business language, 'strategy'. Once the basis on which the preliminary views expressed by past researchers on the concept of BM is understood, it will be necessary to review the literature once again to get an understanding of the BM elements, BM design, BM changes and BM innovations, so that the concept of BM in the construction business environment and culture could be fully grasped.

Keywords:*Business Model; Construction Business; Definitional Views; Strategy.*

1. INTRODUCTION

Construction industry caters to several distinctive markets such as new building works; civil engineering works; specialist works; repairs and maintenance; and decoration works. There is a demand for the products and services provided by the construction industry from its customers to meet their own business and operational needs (Brady *et al.,* 2005). Therefore, in order to acquire a long term business perspective, construction firms can develop and offer total solutions for their products throughout their life-cycles including their design, construction, operation and maintenance with a view to enhancing the sustainability of the products (Kujala *et al.,* 2010). However, businesses will fail to either deliver or capture value from their products, services or their business perspectives if they do not have a well-developed Business Model (BM) (Teece, 2010). To put it more strongly, businesses in spite of having adequate resources, market opportunities, new business ideas and talented staff, can fail in the absence of proper business models that can drive them towards success (Morris *et al.,* 2005). According to Stefan and Branislav (2016), every company that makes money has a functioning BM (p.72), because BMs satisfy customers by producing value while getting the companies to earn profits through revenues that exceed costs.

Construction businesses continuously confront challenges that arise from outside due to economic uncertainties, the globally competitive construction market and the influence of the regulatory bodies: they also face challenges that arise within the businesses themselves due to increased features and complexity of project scopes, tightly programmed and shorter construction deadlines, increasing number of project participants and limited budgets (Antunes & Gonzalez, 2015).Thus, compared to their counterparts in other industries, construction businesses are in a risky situation and are required to adapt themselves continuously to the complex and changing construction business environment (Odediran *et al.,* 2013). The application of

*Corresponding Author: E-mail – dilaniabeynayake@yahoo.com

BMs will help to deal with these complexities and provide a means of identifying, describing, and analysing the different value networks available (Arend, 2013).

With the basic understanding of the importance of BMs for businesses irrespective of the industry or sector in which they operate, there has been an increasing interest in understanding the concept of BM fully. It is obvious that a good understanding of the BM concept will provide for improvements in company and industry applications. Zott *et al*. (2011) have stated that the use of the business model concept can tackle different research questions in different contexts as well as in management areas like construction business management. However, the concept of BM has, at times, been misperceived due to its newness and the unfamiliarity of the disciplines (such as information systems, e-Business and e-Commerce) and sectors (such as telecommunication and software industries) within which the BM concept has been mostly investigated and applied (Al-Debei & Avison, 2010). Therefore, this paper aims to review the existing literature to get a better understanding of the BM concept so that it could be used as a first step towards ensuring the success and sustainability of businesses in the construction industry. The paper also highlights, (a) definitions and different perspectives of BM concept, (b) difference between BM and the commonly used word 'strategy' and (c) the significance and role of BMs which will help to identify the pre-dominant characteristicsof BM.

2. RESEARCH METHOD

As stated by Saunders *et al*. (2009), a preliminary search of literature will help to generate and refine a research idea whereas a critical review of the literature will help to give a thorough understanding of previous researches related to the subject. Thus, the goal of the paper is to understand through a preliminary literature survey, the concept of BM while clarifying the term "BM" against the term "strategy". In order to understand the BM concept more precisely, the definitions given in 31 articles that covered a considerable number of different angles from which the BM concept has been observed over the period from 1998 to 2016 were studied (Table 1). Using content analysis, eight general notions around which the BM definitions given in those 31 articles were centred, were also identified and named as stakeholder based, value based, revenue based, strategy based, process based, causality based, element based and dynamicity based notions.

3. BUSINESS MODEL DEFINITIONS AND PERSPECTIVES

Since there is no generally accepted definition for the term "Business Model", it is challenging to identify the nature and components of a BM and determine what constitute a good BM (Morris *et al.,* 2005). Hence, this section will focus on identifying the various perspectives of the BM concept. Fundamentally, BM is concerned as sense of profit generation. In this backdrop, Stewart and Zhao (2000, p. 290) have defined BM as a statement of how a firm will make money and sustain its profit stream overtime. In broad terms, BM can be described as the architecture of revenues, costs and profits connected with the business that creates and delivers value to customers while providing data and evidence that demonstrate how to create such value (Teece, 2010). Zott and Amit (2008, p.3) have defined business model as a structural template of how a focal firm transacts with customers, partners, and vendors: that is, how it chooses to connect with factors and product markets. According to Arend (2013), BM is a useful way of showing how an organization creates value through transforming and transferring substances using available factors. Frankenberger *et al*. (2013) have defined BM simply as a unit of analysis that describes how the business of a firm works while Beattie and Smith (2013) have identified it as a system-wide description of how companies do business. Thus, in the literature, different researchers have given different definitions to BM. However, as can be seen from Table 1, most researchers define BM as a way of creating value for customers (Magretta, 2002; Kallio *et al.,* 2006; Rajala & Westerlund, 2007; Chesbrough, 2007; Johnson *et al.,* 2008; Teece, 2010; Casadesus-Masanell & Ricart, 2011; Arend, 2013; and Mutka & Aaltonen, 2013). In the next section, a further clarification of the BM concept is given through the notions identified.

4. NOTIONS IDENTIFIED FROM THE BM DEFINITIONS

Table 1 indicates that all BM definitions are related to one or more of the notions identified: as stakeholder based, value based, revenue based, strategy based, process based, causality based, element based and dynamicity based notions. Stakeholder based notion come into play when the various stakeholders of a business such as customers, partners, competitors and the government and their associated roles are considered when defining BM (Timmers, 1998; Hedman & Kalling, 2003; Rajala & Westerlund, 2007; Casadesus-Masanell & Ricart, 2011; and Mason & Spring, 2011). Authors like Timmers (1998); Magretta (2002); Osterwalder (2004); Kujala et al. (2010); Teece (2010); Baden-Fuller and Mangematin, (2013); and Boons and Lüdeke-Freund (2013) have connected their BM definitions with the generation of revenue, profit and money for the business and the associated notion is thus considered as a revenue based notion. The most common key word found in BM descriptions/definitions is 'value' which is in the form of value creation, value proposition and value capture. Accordingly, "value based" notion is taken into consideration as a fundamental notion.

Successful companies have operational and managerial processes which include recurrent tasks that deliver value to their customers (Johnson et al., 2008). Processes also yield performance benefits with more clever deployment of resources to offer superior efficiency and effectiveness of the firm (McGrath, 2010). Accordingly, some definitional views such as those provided by Hedman and Kalling (2003); Rajala and Westerlund (2007); Chesbrough (2007); Johnson et al. (2008); McGrath (2010); Onetti et al. (2012); Beattie and Smith (2013) and Stefan and Branislav (2016) comprise firms' processes and tasks of business actors, lead to the process based notion.

The use of BMs either in a static sense or in a dynamic sense is essential for the success of a business (Beattie & Smith, 2013). Furthermore, as stated by Cavalcante *et al*. (2011), the two main purposes of a BM are to provide stability to develop a firm's activities and to provide flexibility to allow changes. Therefore, to survive and succeed in dynamic business environments filled with internal changes and exogenous shocks like changes in technology and regulations, businesses including construction businesses are required to design BMs to suit optimal changes (Martins *et al.,* 2015). Hence, it could be argued that the "dynamicity based" notion is somewhat important to BM definitions. However, only few authors namely; Hedman and Kalling (2003); McGrath (2010); Demil and lecocq (2010); and Arend (2013) have included the perspective of change in their BM definitions.

Some authors have explained their perception about BM based on its elements (Hedman & Kalling, 2003; Osterwalder, 2004; Johnson *et al*., 2008; Demil & lecocq, 2010; Sabatier *et al.,* 2010; Stefan & Branislav, 2016) which lead to the element based notion. Baden-Fuller and Mangematin (2013) have stressed that embedding the cause and effect relationship into BM would provide a better understanding of the world of business and have therefore defined BM as a stripped-down characterization that captures the essence of the cause–effect relationships among customers, the organization and money, which leads to the causality based notion.

As stated by Teece (2010), a strategy assures a competitive advantage for a business while BM is about creating and delivering values to customers to ensure a competitively sustainable business. Moreover, according to Stefan and Branislav (2016), BM has a strategic importance to a company as it is a fundamental and existential phenomenon on which strategy grows. Therefore, it could be argued that most of the BM definitions have a hidden strategy based view and thus the strategy based notion can be considered as an important definitional view of BM. Meanwhile, the term "Strategy" in business literature is required to be distinguished from the term BM.

Table 1: Business Model Descriptions Identified from the Selected Articles

Reference	Description given to BM
Timmers (1998, p.02)	An architecture for the product, service and information flows, including a description of the various business actors and their roles; and a description of the potential benefits for the various actors; and description of the sources of revenue.
Petrovic *et al.* (2001, p.02)	Organization's core logic for creating value.
Magretta (2002,p.04)	A story that explains how enterprises work and answers the questions: Who is the customer and what does the customer value? It also answers the fundamental questions every manager must ask: How do we make money in this business? What is the underlying economic logic that explains how we can deliver value to customers at an appropriate cost?
Hedman and Kalling (2003, p.49)	A term used to describe the key components of a given business; customers, competitors, offers, activities and organization, resources, supply of factors and production inputs as well as longitudinal process components to cover the dynamics of the business model overtime.
Osterwalder (2004, p.15)	A conceptual tool that contains a set of elements and their relationships and which allow for expressing a company's logic of earning money.
Shafer *et al.* (2005, p.203)	A model that facilitates analysis, testing, and validation of a firm's strategic choices.
Osterwalder *et al.* (2005, p.05)	A conceptual tool containing a set of objects, concepts and their relationships with the objective of expressing the business logic of a specific firm.
Andersson *et al*. (2006, p.01)	A model created to identify the main actors in a business and the values transferred among them.
Kallio *et al.* (2006, p.282 and p.283)	Means by which a firm is able to create value by coordinating the flow of information, goods and services among the various industry participants including customers, partners within the value chain, competitors and the government, with whom it comes into contact
Rajala and Westerlund (2007, p.118)	A way of creating value for customers through which a business turns market opportunities into profit through a set of actors, activities and collaboration.
Chesbrough, (2007, p.12)	A model that performs value creation and value capture while identifying and capturing value from a seriesof activities, from procuring raw materials to satisfying the final consumer.
Johnson *et al*. (2008, p.60)	A model consisting of four interlocking elements that taken together create and deliver value.
Zott and Amit (2008, p.03)	A structural template of how a focal firm transacts with customers, partners, and vendors: that is, how it chooses to connect with factor and product markets.
Kujala *et al.* (2010, p.98)	A model used for describing the underlying logic for supplier's revenue and profit generation.
McGrath (2010, p.248)	A model that suggests a change to the way that strategies are conceived created and executed.
Teece (2010, p.173)	Architecture of revenues, costs and profits connected with the business creating and delivering value to customers.
Demil and lecocq (2010, p.231)	A blueprint for the coherence between core BM components and a tool to address change and innovation.
Sabatier *et al*. (2010, p.433)	A recipe in which BM elements characterize ingredients, and then 'match' these elements to the business model portfolio concept which highlights the specific combination of resources required to deliver value propositions.

Reference	Description given to BM
Casadesus-Masanell and Ricart (2011, p.09)	Logic of the company as to how it operates, creates and captures value for stakeholders in a competitive marketplace.
Mason and Spring (2011, p.1033)	A frame for action which allows front-line workers to translate, adapt and act in contextually appropriate ways and practices
Onetti *et al.* (2012, p.24)	Way a company structures its own activities in determining the focus, locus and modus of its business.
Baden-Fuller, and Mangematin (2013, p.419 and p.424)	A stripped-down characterization that captures the essence of the cause–effect relationships among customers, the organization and money A 'manipulable instrument' which can be used to explore cause and effect and understand the world of business better.
Boons and Lüdeke-Freund (2013, p.10)	A plan which specifies how a new venture can become profitable and a reference point for communication among different actors.
Arend (2013, p.2)	A useful representation of how the organization creates value through transforming and transferring matter, and by drawing on available factors, fuelled by an identifiable economic engine.
Beattie and Smith (2013,p.15)	A system-wide, description of how companies do business.
Frankenberger *et al.* (2013)	A unit of analysis to describe how the business of a firm works.
Mutka and Aaltonen (2013, p.168)	A model that conceptualizes the way in which a firm creates and captures values and comprises of the strategic choices, the organizational architecture and the economics of the firm.
Kindström *et al.* (2015)	A tool to visualize changes, which should increase internal transparency, understanding, and awareness of service opportunities and necessary changes.
Martins *et al.* (2015, p.17)	A distinct and strategic construct that explains the logic for a firm's value creation and capture.
Wirtz *et al.* (2016, p.41)	A simplified and aggregated representation of the relevant activities of a company which show marketable information, products and/or services generated by means of a company's value added components.
Stefan and Branislav (2016, p.72)	A model that portrays and displays the picture of company resources, which are grouped and arranged in a process to produce values to customers and earnings for firm and thus solves an elementary sense of company existence.

5. BUSINESS MODEL VS STRATEGY

According to Magretta (2002), when BM acts as a system that explains how the pieces of a business are integrated, the strategy will deal with the real critical dimension of performance like competition. Similarly, Casadesus-Masanell and Ricart (2010) have considered BM as the logic of the firm in terms of how it creates value for its stakeholders whereas strategy refers to picking the business model through which the firm will compete in the marketplace. As stated by Teece (2010), BM is more generic than strategy due to its features; transparency and ease of imitation. Thus, combinations of business models could be used by strategists to create new strategies for new or existing businesses by blending and matching various combinations of business models (Seddon & Lewis, 2003). The strategies in turn can be used as contingency plans to decide on the business models to be used or even the modifications required to BMs when contingencies take place (Casadesus-Masanell & Ricart, 2010). Specifically, Ho (2016) describes a strategy, in relation to the construction industry, as a mechanism by which the contractor is linked to the competitive industrial environments. However, BM can also become a source of competitive advantage through BM innovation (Boons & Lüdeke-Freund, 2013) which is a consequence of strategy. Hence, the competitive advantage of designing a new BM can be protected by combining strategy and BM (Teece, 2010).

6. ROLE OF THE BUSINESS MODEL AND ITS SIGNIFICANCE

It is evident that the high quality business decisions that will enhance competition and provide the ability to face rapid environmental changes can be supported by implementing suitable BMs (Al-Debei & Avison, 2010). Some of the examples of this as highlighted by Baden-Fuller and Morgan (2010) are South-West Airlines, Google, Disney and Toyota. According to Table 1, the definitional views given to the business model vary widely: it is referred as an architecture (Timmers, 1998; Teece, 2010), a logic (Petrovic *et al.,* 2001; Kujala *et al*., 2010; Casadesus-Masanell & Ricart, 2011; Martins *et al.,* 2015), a story (Magretta, 2002), a structural template (Zott & Amit, 2008), a stripped-down characterization (Baden-Fuller & Morgan, 2010), a recipe (Sabatier *et al.,* 2010), a tool (Osterwalder, 2004; Osterwalder *et al.,* 2005), a system-wide description (Beattie & Smith, 2013) and a 'manipulable instrument' (Baden-Fuller & Mangematin, 2013). Thus, this section focuses on identifying the multipurpose nature of BMs. Aho (2013) highlights the key points that a BM addresses: how the value proposition of the enterprise is defined, to whom value is created, how value is created, what resources and competencies are utilized and how revenue streams are created. Casadesus-Masanell and Ricart (2011) have introduced three characteristics of a good BM which can benefit a company. They are; the alignment with the company's goals; self- reinforcement; and robustness. Cavalcante, Kesting and Ulhoi (2011), on the other hand, have highlighted, creating stability for the development of a company's activities and flexibility for allowing changes as the two interlinked functions of a BM.

In Table 2, the different roles of BM as stated by various authors are presented, which indicates that BM can have many characters. According to Baden-Fuller and Morgan (2010), BM can play different roles for different firms and for different purposes, often playing multiple roles at the same time. An organization will be able to benefit by using the BM that is most appropriate to its business. Especially, when operating in complex and information-intensive environments and when dealing with parties who differ widely in their interfaces, capabilities, and motives as those in the construction industry, the characteristics of BMs such as transparency, transferability, scalability, tracking, and robustness would become useful (Arend, 2013).

It could be proved that a good BM can become a powerful tool for improving the running of a company (Magretta, 2002). Magretta (2002) further explained this with the "story of Dell Computers", i.e. "BM of Dell Computers", which is used by Dell as a basis for employee communication and motivation resulting everyone in Dell to see their own jobs within a large context thereby creating the kind of value required by the firm. Nokia's Mobile phone business declined mainly due to its failure to grasp the market accurately, deviations made in the business tactics of the company and lack of teamwork (Jia & Yin, 2015). Thus, to avoid such decline, businesses need to have proper BMs which function as a source of competitive advantage (Zott & Amit, 2008), a source of change (Martins *et al.,* 2015), a cognitive tool of visualization and a common language (Arend, 2013).

Table 2: Multivalent Characteristics of BM

Character/role	Function	Reference
Narrative device	Describes and validates the selection of entities to be taken into account focusing on story-formation and cataloguing.	Doganova and Eyquem-Renault (2009)
Calculative device	Connects or disconnects existing entities to create new entities which will then play the characters of the BM story.	Doganova and Eyquem-Renault,(2009)
Generic level descriptor	Provides how a firm organizes itself to create and distribute value in a profitable manner.	Baden-Fuller and Morgan (2010)
Conceptual tool of alignment	Fills the gap between corporate strategy and business processes to provide central coordination among those organizational layers.	Al-Debei and Avison (2010)
Interceding framework	Mediates technological artifacts and the fulfillment of strategic goals and objectives.	Al-Debei and Avison (2010)
Strategic-oriented knowledge capital	Demonstrates the ways in which businesses are performed and strategic objectives are achieved.	Al-Debei and Avison (2010)
Cognitive tool of visualization	Spots and addresses gaps and inconsistencies in the overall set of operations of a business.	Arend (2013)
Opportunity facilitator	Intermediately assists in the opportunity creation process.	Amit and Zott (2001)
Common language	Combines stakeholders by reducing complexities and improving understanding.	Arend (2013)
Source of change	Responds to internal changes of the organization and external shocks.	Martins *et al.* (2015)
Source of competitive advantage	Supports strategic decision making in gaining a competitive advantage.	Zott and Amit (2008)
Exemplar role	Might be copied, imitated or compared.	Baden-Fuller and Morgan (2010); Doganova and Eyquem-Renault (2009)
Scientific role	Acting in the scientific sense as model organisms for investigation.	Baden-Fuller and Morgan (2010)
Scale model	Shows feasibility and worth to the partners of new business enterprises.	Baden-Fuller and Morgan (2010); Doganova and Eyquem-Renault (2009)
Recipe	Combines resources to produce a particular outcome to deliver value proposition.	Sabatier *et al.* (2010)

7. CONCLUSIONS AND THE WAY FORWARD

This literature review first obtained a preliminary understanding of the concept of BM and thereafter on finding answers to vexing questions such as "What is BM?" and "What does BM do?" The paper also briefly discusses the relevance and importance of BM to the construction businesses. Irrespective of the nature of the business or industry in which the company is engaged, a sound BM will be fundamental to the success of a company whether it is new or established (Magretta, 2002; Johnson et al., 2008; Teece, 2010). The main BM of a company or an industrial sector basically defines and evaluates the service that company/ industry sector is actually delivering to their customers and how the price level of that service is defined (Aho, 2013). It was revealed from the review of 31 articles that definitions given to the BM are focussed around eight notions which are related to stakeholders, value, revenue, strategies, processes, causality, elements and dynamicity. Also, the researchers believe that BMs are based on one or more of these notions. Even though value creation and value capture are the two key functions of BM, it is evident from the literature that BM has a multivalent character as a model. To be more precise and as presented in Table 2, it acts as a cognitive tool of visualization; an opportunity facilitator; a common language; a source of industry change; a source of competitive advantage; an exemplar etc.

Although the concept of BM is relatively new, it has already been used in various contexts: in the manufacturing industry, telecommunication industry, software industry and e-Government (Al-Debei & Avison, 2010). Towards enabling research on the merger of the construction business with the BM concept, this paper attempted to converge into one common understanding the different perspectives that different researchers from various disciplines have on BM. However, further studies will be necessary to identify the different components of BM, interactions among the individual components of BM, key players of BMs and their roles which will depend on the nature of the business and the industry. In addition, factors affecting the decency and quality of a BM in relation to the success and sustainability of the associated business also need to be verified. It will also be important to study BM innovations and changes as it will help to identify the economic value of new products, new services, new ideas and new technologies (Chesbrough, 2010).

It has also to be noted that this study was focussed on the preliminary issues that have been already identified by past researchers, to gain an understanding of the concept of BM while at the same time identifying few other aspects of the concept that need to be given attention in the future to completely eliminate the fuzziness of the concept before it could be applied to construction businesses. In the meantime, as the construction businesses are mainly project-based businesses, clarification of BM concept in both firm level and project level is also required in future. As Rasmussen (2007) tried to enrich the concept of BM with various theoretical concepts based on the theory of the firm by identifying relevant theories and their implications with respect to functions of BM for pharmaceutical industry, a similar research could be done for construction industry as a separate research path.

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CAN LEADERSHIP STYLES INFORM SAFETY OUTCOMES IN SAFETY-CRITICAL ORGANISATIONS? A REVIEW OF LITERATURE

John Ojuola and Sherif Mohamed*

School of Engineering & Built Environment, Griffith University, Gold Coast, Queensland, Australia

ABSTRACT

Safety-critical organisations (SCOs), such as the military, fire service, aviation, emergency services, and construction, are characterised by being organisations with high potential for stress, accidents, and injuries. Environments where safety is highly critical (i.e., high exposure to risk and likelihood of an accident) - poses particular challenges for leaders. Thus, such environments call for specific leadership/ leadership style, which differ from those most effective in less safety-critical environments. Most research literature seems to associate leadership with traditional, linear models, which are incongruent with the behaviour of a complex system, such as the construction industry. Thus, the objective of this paper is to fill this research gap by: (1) critically reviewing relevant literature; (2) investigating the effect of leadership styles (LS) on safety outcomes, with emphasis on SCOs; and (3) developing a conceptual framework for empirical testing. A survey design will be applied to collect data from project managers in the construction industry within the Australian context. This paper presents a brief description of the effect of various LS on safety outcomes, using the principles of complexity science. The results of this study will present the effect of riding on the principles of complexity science to provide the premise for flexible responses to emerging patterns and opportunities in the construction industry.

Keywords: *Complexity Science; Leadership Styles; Safety Leadership; Safety Outcomes.*

1. INTRODUCTION

The way safety is managed in an organisation depends heavily on the beliefs and assumptions the management and personnel have concerning organisational behaviour and safety. Both researchers and practitioners within the safety field have tended to focus on an absence of negative events as being a proof of safety. Variance in human activity has been a major causal factor in accidents and incidents. Safety management has thus focused on identifying the possible ways things can go wrong, and then seeking to prevent such possible deviations by implementing barriers, emphasizing procedural adherence, creating redundant systems, supervising work and making clear the distribution of responsibilities. The numbers of accidents and other negative events, such as breakdowns, adverse events and process leaks, have been used as indicators of safety. This classical safety management paradigm views organisations as machine-like entities (Reiman et al., 2015). However, disappointments in the results achieved by the classical safety management paradigm together with the evolution in several scientific disciplines have led to an emerging view of safety as something more than the negation of risk. This new paradigm for safety management is supported by an increased application of complexity theories in safety science (Dekker et al., 2011; Dekker & Pruchnicki, 2014; Goh et al., 2010).

Researches in various safety consultancy projects in different safety-critical fields has led to the realization that many managers and experts in safety–critical domains experienced contradicting demands but lacked a theoretical framework to conceptualize what management principles they needed for trade-offs and balancing (Quinn & Rohrbaugh, 1983; Quinn et al., 2006). Thus, an investigation into how various LS can inform safety outcomes in SCOs is of paramount importance.

*Corresponding Author: E-mail – s.mohamed@griffith.edu.au

2. LITERATURE REVIEW

The literature review provides a clear understanding of the research topic by giving details of various LS by their key characteristics. A breakdown of the technical components of safety are also discussed. Finally, the current state of complexity science is reviewed; in the light of how LS can determine safety outcomes in SCOs.

2.1. SAFETY

Most people think of safety as the absence of accidents and incidents (or as an acceptable level of risk). Hollnagel et al., (2013) defined safety as a state where 'as few things as possible go wrong'. A condition where the number of adverse outcomes (accidents/incidents/near misses) is as low as possible. This is achieved by trying to make sure that things do not go wrong, either by eliminating the causes of malfunctions and hazards, or by containing their effects. According to this definition, things go wrong due to technical, human and organisational causes – failures and malfunctions. However, since work situations are increasingly intractable, despite the best intention to avoid that, another definition of safety could be 'ensuring that everything goes right' (Hollnagel et al., 2013). This is a condition where the number of successful outcomes is as high as possible. It is the ability to succeed under varying conditions. And this is achieved by trying to make sure that things go right, rather than by preventing them from going wrong.

Hollnagel et al., (2013) concluded by emphasising that both ways of thinking represent two complementary views of safety rather than two incompatible or conflicting approaches. The specific balance of both approaches depends on the nature of the work, the experience of the people, the organisational climate, management and customer pressures, and a number of other variables.

2.2. LEADERSHIP

Leadership is a personal relationship in which one person directs, coordinates and supervises others in the performance of a common task. Leadership is a matter of aligning people towards common goals and empowering them to take the actions needed to reach them. The ability to influence individuals/group towards the achievement of a common goal (Yukl, 2013; Khan et al., 2015).

Leadership is increasingly being recognised as a key factor in supporting successful performance across a range of domains (Cameron & Quinn, 2011). Leadership can also be defined as a process of social influence in which a person can enlist the aid and support of others in the accomplishment of a common goal (Donovan et al., 2016).

2.2.1. LEADERSHIP STYLES AND THEIR KEY CHARACTERISTICS

The terminology style is roughly equivalent to the *leader's behaviour*. It is the way in which the leader influences the followers. There are many ways to lead and every leader has his/her own style. A thorough literature search was conducted by Hassan et al., (2016) to identify the existing LS and derive a framework for systematically arranging these styles into groups. The leadership labyrinth under the realm of three main scientific paradigms i.e. Trait, Behaviour and Contingency has extended to various styles. The constituent leadership styles of the three paradigms, frequently discussed and comparatively well-articulated in literature include autocratic, bureaucratic, charismatic, democratic, laissez-faire, transactional and transformational LS. Other forms are ethical, authentic and adaptive LS (Hassan et al. 2016).

In the past several decades, management experts have undergone a revolution in how they define leadership and what their attitudes are toward it. These experts have defined leadership from a very classical autocratic approach to a very creative, participative approach. Somewhere along the line, it was determined that not everything old was bad and not everything new was good. Rather, different styles were needed for different situations and each leader needed to know when to exhibit a particular approach (Khan et al., 2015).

The unabridged list of LS mentioned above is presented in Table 1 enlisting the characteristics of each style along with few references.

Table 1: List of Leadership Styles and their Key Characteristics (Adapted from Hassan et al., 2016)

Leadership Style	Key Characteristics	Referred by
1. Autocratic leadership	Punitive, less concerned for socio-emotional dimension of group, dominating, dictatorial, unilateral decision making	Foels et al. (2000); Van Vugt et al. (2008)
2. Bureaucratic leadership	Follows rules vigorously, ensure that subordinates also follow procedures precisely	Schaefer (2005); Santrock (2007)
3. Charismatic leadership	Strategic vision, unconventional behaviour, agents of exchange, sensitive to the needs of followers, risk oriented, extrovert	Hunt (1999); Gregory et al. (2004); De Hoogh et al. (2008)
4. Democratic leadership	Considerate, participative, concerned with maintaining relationships with others, group decision making	Gastil (1994); Foels et al. (2000); Woods (2004)
5. Laissez-Faire leadership	Lack of involvement, avoidance of responsibilities, resistance in discussing critical issues	Bass (1997); Skogstad et al. (2007)
6. Transactional leadership	Leader-Follower exchanges, clarification of subordinate responsibilities, contingent rewards	Bass et al. (2003); Van Vugt et al. (2008)
7. Transformational leadership	Vision, inspirational communication, intellectual stimulation, influence, empowerment, high performance expectations	Bass (1997); Avolio et al. (1999); Jung and Avolio (2000)
8. Ethical leadership	Awareness for others, considerate, honest, altruistic, caring, principled, internal locus of control, proactive, co-operative	Brown & Trevino (2006); Toor & Ofori (2009); Walumbwa et al. (2011)
9. Authentic leadership	Morally courageous, pro-social behaviour, reliable, honest, social justice and equality, optimistic, self-disciplined, self-expressive	Avolio & Gardner (2005); Hannah et al. (2011)
10. Adaptive leadership	Influences change (changes behaviour in appropriate ways as the situation changes), taps into human potential to make positive change, sees organisations as living – not mechanical – systems.	Bryman (1996); Lichtenstein et al. (2006)

2.2.2. REPRESENTATIVE LEADERSHIP STYLES

Below (see Table 2) are five representative styles (LS1-LS5) which are non-mutually exclusive. These representative styles have been developed by utilizing a common frame of reference i.e. focus on leader and centralization of decision making (Hassan et al. 2016).

Table 2: Representative Leadership Style (Adapted from Hassan, et al., 2016)

Critical Areas	LS1	LS2	LS3	LS4	LS5
Role of Leader	Clearly defined instructions and performance standards	Encourage participation	Seek highest standards of excellence	Assist followers	Leave followers to do task themselves
Leader's concern for others	Little	High	High	Very high	Little or None
Distance from followers	High	Moderate	Low	Low	High
Leader's decision-making style	Unilateral	Shared decision making through followers	Shared decision making by persuasion	Shared decision making in the interest of followers	Minimal or no role in decision making
Followers' motivation	Followers are incapable of performing tasks themselves and are moderately motivated	Followers are equal with the leader and are highly motivated	Followers identify with the leaders and are highly motivated	Followers try to reach their level of self-fulfilment	Followers are frustrated and unmotivated

Critical Areas	LS1	LS2	LS3	LS4	LS5
Focus on followers' growth	None as leader emphasizes followers only to follow instructions	Moderate as leader provides training and development to the followers	Moderately high as leader focus on the competence development of followers	High as leader's top priority is to help others achieve their goals	None as leader remains uninvolved

*LS1-LS5 indicates leadership styles 1-5

The six critical areas (i.e. role of the leader, leader's concern for others, distance from followers, leader's decision-making style, followers' motivation and leader's focus on followers' growth) have been selected to view the difference in the five different styles, as they all are essential components of leadership.

Based on these characteristics of representative leadership styles, an amalgamation of the 10 LS identified are shown in Table 3 below.

Table 3: Leadership Styles Clustered into Five Representative Styles Based on Common Characteristics (Adapted from: Hassan et al., 2016)

LS1	LS2	LS3	LS4	LS5
Autocratic	Democratic	Transformational	Ethical	Laissez-faire
Transactional		Charismatic	Authentic	
Bureaucratic			Adaptive	

*LS1-LS5 indicates leadership styles 1-5

2.3. SAFETY LEADERSHIP

Safety leadership is a sub-system of leadership and can be defined as "the process of interaction between leaders and followers, through which leaders can exert their influence on followers to achieve organisational safety goals under the circumstances of organisational and individual factors" (Wu et al., 2016). Leadership is fully implicated in safety. Safety leadership is an important factor in supporting safety in SCOs.

Safety literatures demonstrate a clear positive link between leadership and *safety outcomes* (Kelloway et al., 2006; Zohar 2002). Some authors claim that active *leadership behaviour* (which includes aspects of surveillance, proactive behaviours towards potential deviances, and feedback about mistakes) is also a critical dimension that should be empirically studied (Clarke, 2013). Positive links have thus been established between various forms of *safety leadership*, and a range of individual and group *performance* and *outcome* variables, such as workforce *compliance* and *participation* (Clarke and Ward 2006; Martínez-Córcoles et al., 2012), and *safety climate* (Hystad et al., 2013; Zohar & Luria, 2005). Martínez-Córcoles and Stephanou (2017) defined *Safety climate* as the employees' shared perceptions about their work environment in terms of safety. Spencer and Spencer (2008) defined *competence* as a personal trait which can influence behaviour and performance. Boyatzis (1982) also defined it as the "underlying characteristics of a person that leads to or cause effective and outstanding performance".

Gaining an understanding of the factors that influence employees' *safety performance* can prove vital for reducing the incidence of job-related injuries (Neal & Griffin, 2006). Neal et al. (2000) have highlighted two dimensions of *safety performance*: *safety compliance* defined as ''adhering to safety procedures and carrying out work in a safe manner'' and *safety participation*, defined as ''helping co-workers, promoting the safety programme within the workplace, demonstrating initiative and putting effort into improving safety in the workplace''. Specifically, *safety compliance* consists of behaviours that are viewed as part of employees' formal job description, while *safety participation* includes behaviours, which are discretionary and extend beyond employees' formal work role (Neal et al., 2000; Neal & Griffin, 2006).

2.4. PRINCIPLES OF COMPLEXITY SCIENCE

Leadership continues to be associated with traditional, linear models, which are incongruent with the behaviour of a complex system, such as the construction industry. However, Plsek and Greenhalgh, (2001) suggest abandoning models of linearity for complexity science, which provide the premise for a flexible response "to emerging patterns and opportunities".

Traditional LS remain entrenched in current bureaucratic structures that emphasize trait-based models and the "dyadic relationships between leaders and follower" (Weberg, 2012). Weberg's review of traditional leadership theories implies that the goal for a leader is to "control uncertainty and work toward absolute stability". He goes on to say that it is these very linear traditional leadership models that have produced the fragmented systems that we have now. He suggests that leadership based on complexity science can provide a different and improved way of leading in organisations.

As the study of complex systems primarily focuses on the relationships between parts, patterns of behaviour and interdependencies within a dynamic system, applying the same principles to safety and leadership provides guidance in practice and presents an alternative leadership model that enables managers to embrace leadership suitable for the twenty-first century. There is greater demand for leadership that understands and values the nature of this high level of interactivity. Strategies to develop leaders who are able to function well in this complex system which is based on complexity science are likely to be more relevant than using traditional hierarchical approaches to leadership. These traditional approaches are not only outdated but incongruent with system (organisational) behaviour. The scientific principles of complexity views leadership as a process that involves many individuals. Complexity science emphasizes the adaptability, creativity and flexibility of leadership, not as a set of values existing in any one individual. In the words of Gareth Morgan, "Leadership is a verb and a process, not a noun" (Morgan, 2006).

The five principles of complexity science are connectivity, interdependence, feedback, exploration-of-the-space-of-possibilities and co-evolution. Based on Mitleton-Kelly's (2003) work, the five principles are grouped into three areas: relationships between agents (encompassing connectivity, interdependence, and feedback), patterns of behaviour (exploration-of-the-space-of-possibilities) and enabling functions (co-evolution).

2.4.1. RELATIONSHIP BETWEEN AGENTS

The concepts of connectivity, interdependence and feedback will better help to understand the quality of relationships between agents; in this case, LS in safety-critical organisations, and its effect on safety-outcomes. According to Mitleton-Kelly (2003), "connectivity and interdependence means that a decision or action by any individual (group, organisation, institution, or human system) may affect related individuals and systems". Thus, LS can be seen as influential in fostering crucial relationships and play a valuable role as agents to determine safety outcomes.

2.4.2. PATTERNS OF BEHAVIOUR

Generating variety in strategies is referred to by Mitleton-Kelly (2003) as exploration-of-the-space-of-possibilities. Less dependent on "pin-point forecasting, top-down planning, or elaborate controls" (Weberg, 2012), natural system behaviour morphs to create a new structure through exploration. The ability to explore allows organisations to identify multiple strategies before a significant investment of resources is made. Exploring the space of possibilities and generating variety through the lens of new strategies and new ways of doing things is suitable for SCOs.

Behaviour patterns in teams are formed over time and processes can become ingrained. The dynamic nature of complex systems requires that processes change as needed and that teams demonstrate a nimbleness that can provide the fluidity to adapt. Leadership behaviour is instrumental to either the encouragement or discouragement of a team's ability to embrace change, including its capacity for generation of new ideas or to be innovative.

2.4.3. ENABLING FUNCTIONS

Mitleton-Kelly (2003) differentiates between co-evolution and adaptation as change that is seen in relation to "all other related systems" and not simply adapting to a "separate and distinct environment". For instance, in a social system, each "fully participating agent" "both influences and is influenced by" the related agents or organisations. Within SCOs, leaders are influenced by unique forces because of their specific tasks, their professional affiliations and their role in the organisation. Looking at how each co-evolve and influence change can provide some insight on how best fit can be determined and where collective leadership capacity can be most valuable.

Interactions among team members, external influences, such as government or suppliers, and political, cultural or economic forces vary all the time with each entity evolving constantly but together or co-evolving. The evidence indicates that "systems thinking" is required for effective leadership and that chaos should be seen as opportunity.

Agents within a complex system are sensitive to fluctuations in the environment. Agents are both the initiator of change and the receiver of influences from other actions within their environment. A heightened sensitivity to the dynamics of complex systems allows for the co-evolution necessary for change and movement within a SCO. According to Anderson and McDaniel (2000), it is when problems become more complex, as in SCOs, "managers need all of the different points of view they can muster".

3. RESEARCH METHODOLOGY

The preceding literature review gave a detailed explanation on how leadership styles can inform safety outcomes in safety-critical organisations. It also emphasised that most literature seems to associate leadership with traditional, linear models, which are incongruent with the behaviour of a complex system - such as the construction industry.

This is a quantitative study in which a survey will be carried out to validate the conceptual model and data analysis carried out. The survey design will be applied to collect data from project managers (research population) in the construction industry within the Australian context. Figure 1 depicts the conceptual research model for this study.

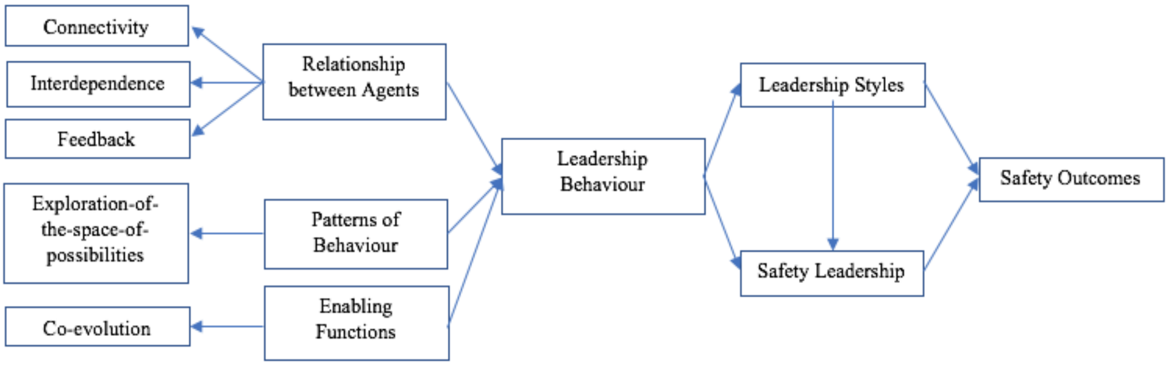

Figure 1: Conceptual Research Model

Relationships between agents, entails ways in which *leaders* can foster relationships, build trust and promote effective feedback to improve *safety outcomes* based on the principles of connectivity, interdependence and feedback in SCOs. *Patterns of behaviour*, explore how *leaders* can encourage team members to try new strategies based on the exploration-of-the-space-of-possibilities principle. *Enabling functions* identify how a *leader* may be an agent of change within an organisation premised on the principle of co-evolution.

4. CONCLUSIONS AND THE WAY FORWARD

This study will shed light on the understanding of the behaviour of various LS, and how they can inform safety outcomes in SCOs. The Structural Equation Modelling (SEM) which is a well-known technique for estimating, analysing and testing models that specify relationships among observed and latent variables (Kline & Santor, 1999) will be used to analyse the relationship between LS and safety outcomes in SCOs. The results of this study will present the effect of riding on the principles of complexity science to provide the premise for flexible responses to emerging patterns and opportunities in the construction industry.

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CHALLENGES IN HOTEL BUILDING REFURBISHMENT PROJECTS IN SRI LANKA

B.J. Ekanayake*, Y.G. Sandanayake and Thanuja Ramachandra

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Amongst the contemporary issues encountered by the buildings, deterioration and obsolescence are in the forefront. The refurbishment has been acknowledged as an avenue to deliver profound solutions to overcome these issues by upgrading, altering, extending, renovating and improving facilities and prolonging building lifespan. Nevertheless, refurbishment projects are uncertain and sophisticated with many challenges. Refurbishment projects in Sri Lanka are dominated in hotel buildings compared to other types of buildings because hotel buildings needed to be upgraded and modified frequently to maintain the tourist attraction intact. Nevertheless, the challenges in these projects remain unprecedented due to lack of in depth investigation. This research therefore, set out to explore the challenges in hotel building refurbishment projects in Sri Lanka. A qualitative approach was applied by focusing on three recently completed hotel building refurbishment projects. Subsequently, data collected through unstructured interviews with the participants involved in the refurbishment projects, document reviewing and observations were analysed using content analysis. The findings revealed topmost challenges as the budget overruns due to superficial designs and construction activities, time overruns due to refining designs to cater unanticipated building conditions, limitations to introduce changes to the existing building structures and the interruptions to building occupants due to simultaneous operations. The budget overruns for Cases A, B and C were reported as 13.64%, 1.38% and 0.95% respectively. The time overruns were calculated as 55.56%, 25% and 50% respectively. These challenges adversely affected in achieving value for money in terms of cost, time, quality, customer satisfaction and sustainability.

Keywords: *Challenges; Hotel Buildings; Refurbishment Projects; Sri Lanka.*

1. INTRODUCTION

For ensuring value enhancement and delivering the required functionality of the buildings, maintenance and preservation of the usable conditions of the buildings are necessitated (Puķīte & Geipele, 2017). Moreover, the growing aged building stock has also forced building owners to seek solutions for improving building condition (Babangida *et al*., 2012). In this context, Mansfield (2009) pointed out that refurbishment can deliver solutions to inevitable physical deterioration and obsolescence of the buildings, and in turn is able to reduce the loss of investment value of the property. Nevertheless, the term "refurbishment" has been loosely defined in past literature. Mansfield (2002) interpreted refurbishment as a physical process, in which the boundaries between the terminologies such as repair, replacement and renewal have not been precisely defined. Regardless of the attempts undertaken to define the term refurbishment, Vilches *et al*., (2017) asserted that alternative terminologies such as refurbishment, retrofitting, renovation, repair or restoration are still being used interchangeably.

Many factors have contributed to creating an increased demand for refurbishment projects. Amongst such contributors, the rise of the ageing building stock, scarcity of land for new construction, adoption of building regulations and requirements on compliance with new standards have fostered an increased demand for refurbishment projects lately (Egbu *et al*., 2002). The benefits yielded through refurbishment projects have been widely discussed in the mainstream literature with a comparison to new constructions and demolition. Refurbishment offers comparatively notable economic, social and environmental benefits over demolition,

*Corresponding Author: E-mail – biyankaje@gmail.com

such as modernising of buildings and enabling energy saving measures (Gohardani & Björk, 2012). Moreover, refurbished buildings produce fewer carbon emissions than new constructions (Power, 2008). In addition to enhancing energy efficiency and reducing adverse environmental impacts, refurbishment improves the noise insulation conditions, external appearance, user comfort and assures healthy working and living environment, whilst prolonging the building life span and increasing the value (Mickaityte *et al.*, 2008). Regardless of the exemplified benefits offered by refurbishment, these projects are sophisticated and uncertain to manage (Egbu *et al*., 2002). Arain (2005) identified twelve (12) most significant challenges associated with refurbishment projects and among them unanticipated time overruns, incurrence of high costs and difficulty of managing due to simultaneous operations conducted by owners are notable. Therefore, the emphasis should be given to managing the complexity and uncertainty of refurbishment projects (Rahmat & Ali, 2010).

Langdon and Everest (2002) explained that refurbishment is vital to hotel buildings in order to uplift building conditions, although these projects are associated with issues in the existing building along with unanticipated cost and time overruns. Regardless of the grooming interest for refurbishment in hotel sector after the tsunami disaster and also with the growth of tourism, these projects are characterised by many challenges (Athapattu & Gunawardena, 2010). The authors explored the causes for the delays in Sri Lankan hotel refurbishment projects. Nevertheless, the challenges in hotel building refurbishment projects in Sri Lanka are yet to be examined critically. Therefore, the present research set out to investigate the challenges in hotel building refurbishment projects in Sri Lanka.

2. LITERATURE REVIEW

2.1. THE SIGNIFICANCE OF REFURBISHMENT PROJECTS

In the building sector, refurbishment is a broadly used term to describe construction activities that aims to raise the standard of a building (Ali et al., 2009). Therefore, building refurbishment represents a significant percentage of turnover in the construction sector (Pereira & Cachadinha, 2011). Although refurbishment sector is important to many construction firms, it is not their sole concern (Rahmat & Ali, 2010), because new building projects allow a certain level of standardisation and choice of materials, equipment and technical solutions to be utilised, whereas the refurbishment projects must adapt to the uniqueness of the existing buildings and adjust to their specifics (Pereira & Cachadinha, 2011). Parameters such as location, orientation and existing construction cannot be altered in existing buildings (Konstantinou & Knaack, 2011). On the other hand, the refurbishment measures signify the starting point of the building's second life (Rasmussen & Birgisdottir, 2016). Amongst the various interpretations on refurbishment, as defined by Quah (as cited in Ali et al., 2009), refurbishment refers to upgrades, major repairs, renovations, alterations, conversions, extensions and modernisation of existing buildings, excluding routine maintenance and cleaning work. Rahmat and Ali (2010) described that refurbishment involves upgrading, alteration, extension and renovation of existing buildings for improving facilities and prolonging building lifespan.

2.2. REASONS FOR UNDERTAKING REFURBISHMENT

According to Ali et al., (2009), refurbishment becomes an alternative, when the building in use fails to perform as expected. The growth of the aging building stock has also induced an escalated demand for refurbishment projects in upcoming years (Kohler & Hassler, 2002). This is primarily because refurbishment offers solutions to physical deterioration and obsolescence in buildings (Mansfield, 2009). Arain (2005) summarised the types of refurbishment and reasons for refurbishment as follows.

- Corrective refurbishment - Failure in buildings
- Space altering refurbishment - Change in use
- Optimising refurbishment - Optimisation of economic factors
- Pleasure refurbishment - Subjectiveness of the decisions of building owners
- Opportunity refurbishment - Change of circumstances

It is evident that refurbishment decision is affected by numerous parameters required by different parties to the project (Konstantinou & Knaack, 2011). During the time span of the building life cycle, refurbishment strategy is an important topic in facilities management agenda, because if the completed building facilities are not maintained properly, they deter delivering the intended performance (Chan, 2014). The author further asserted that building facilities must be maintained to an acceptable condition and must be refurbished to sustain its utilities and value. Hence, determining when refurbishment should be undertaken is of utmost importance.

When the building value is plotted against the time span of the building, it illustrates that typical deterioration in the performance of a building occurs with the passage of time (Jones, 2002). Further to the author, deterioration can be reduced by routine maintenance but repairs should be undertaken from time to time and eventually there will be a need for a major refurbishment, during which performance is likely to be further degraded.

2.3. CHALLENGES IN REFURBISHMENT PROJECTS

Refurbishing the existing building stock is acknowledged as challengeable in the building industry (Konstantinou & Knaack, 2011). Among the challenges, unanticipated rising costs and financial constraints, unanticipated time overruns, limitations to introduce changes to existing structure, lack of drawings and design information, interruptions due to simultaneous operations in the building (Arain, 2005; Egbu et al., 2002; Rahmat & Ali, 2010) are prominent. Moreover, unsafe working conditions, lack of quality parameters and lack of precise definition on the beginning and end of the project (Bryde and Schulmeister, 2012; Lund *et al*., 2016) are also highlighted. Other challenges include selecting the contract type, accumulation of salvaged materials through demolition waste, lack of proper site survey to investigate existing conditions and unreasonable conditions imposed during refurbishment to reinstall certain original building elements (Arain, 2005). Benefits of refurbishment can only be yielded, when the costs and benefits are assessed over the extended life of the building (Mansfield, 2009). The author further stated that ongoing maintenance costs for a refurbished building are high and refurbished buildings have a possibility of misalignment with market demand. Lack of proper communication and coordination among project participants (Juan, 2009; Rahmat & Ali, 2010) and existing building being subject to legislative constraints (Sodagar. 2013) are also challenges encountered during the refurbishment. Lee (2015) pointed out that refurbishment of buildings requires a wide range of skills from the project team, as the process is complicated.

2.4. THE NECESSITY TO ACHIEVE VALUE FOR MONEY IN REFURBISHMENT PROJECTS BY OVERCOMING CHALLENGES

In refurbishment projects, the challenges encountered are peculiar to existing buildings (Rahmat & Ali, 2010) and these challenges could result in subverting value for money. As claimed by Emmitt *et al.,* (2005); Martinsuo and Killen (2014), achieving value for money is the final outcome of all construction projects. Moreover, continuous value enhancement is paramount to reduce missed opportunities, strengthen integration and enhance sustainability in building projects (Pulaski & Horman, 2005). Although different stakeholders of construction projects interpret value from their own perspective (Haddadi *et al.,* 2016), the value of construction projects can be interpreted in terms of function, quality, cost and time (Potts & Ankrah, 2013; Yan, 2012). Jensen and Maslesa (2015) pointed out that lack of simple, yet holistic tools for assisting building owners on decision making during the early stages of projects is notable. Furthermore, Chau *et al.,* (2003) also contended that there seems a lack of empirical evidence on the approaches to enhance the value performance of refurbishment projects, by overcoming the challenges. In light of this, investigating the challenges associated with refurbishment projects and identifying their impact on achieving value for money is necessitated to enhance the value performance of refurbishment projects.

3. RESEARCH METHODOLOGY

This research sought to explore the challenges in hotel building refurbishment projects in Sri Lanka through a qualitative approach. Since the case study approach enables in-depth examination in the context (Fellows and Liu 2008; Yin, 2011), it was considered that the case study approach could facilitate the accomplishment of the aim of this study. According to Yin (2009), either a single case study design or multiple case study design can be undertaken when conducting a case study research. The author further explained that criteria for selecting a case depends on the convenience, judgement, time and cost constraints. Considering all aforementioned factors, three hotel building refurbishment projects, which were undertaken from 2014 to 2017 were investigated in this study.

Yin (2009) pointed out several data collection techniques to be included in case studies research such as interviews, observations and document reviewing. Punch (2005) highlighted interview method as one of the most commonly used data collection method when the research embodies a qualitative approach. The author further explained that there are three types of interviews namely structured, semi-structured and un-structured interviews. Employing un-structured interview method is preferred in qualitative approach since the respondents are given the opportunity to answer independently with a limited control imposed by the researcher (Dawson, 2007). Accordingly, un-structured interviews were conducted for collecting data focusing on selected respondents, who involved in the refurbishment project. Moreover, observations and reviewing relevant documents were undertaken to capture data. The researcher referred documents such as bill of quantities (BoQ), drawings of the design proposals, photographic analysis documents of the project and archival records about the building. The refurbished areas were observed by visiting the hotel building. Table 1 presents the profile of the selected cases and respondents. For qualitative researches, content analysis provides subjective interpretation of texts through a systematic coding and pattern (Hsieh & Shannon 2005). In order to facilitate content analysis of this research, the software called NVivo (2010) was used for code based content analysis along with the manual content analysis.

Table 1: The Profile of the Case Study Hotels and Respondents

Details of the Case	Details of the Respondent
Case A	
▪ Five star rated hotel with 19 story building located in Colombo. ▪ Under phase 1 of refurbishment areas were the, front of house, selected back of house areas, lobby lounge, public toilets in lobby, Chinese restaurant, all day dining restaurant, board walk, MEP services in executive lounge, procurement, and replacement of kitchen and laundry equipment, lotus pond, AHU room, fire commanding centre and lift lobby ▪ The project was traditionally procured and the contract type was the re-measurement contract ▪ Contract price was LKR 220,000,000 and final project cost was LKR 250,000,000 ▪ Planned duration of the project was 9 months but the actual duration of the Project was 14 months	A1: Project manager with 24 years of work experience A2: Cost consultant with 21 years of work experience A3: Lead design consultant with 27 years of work experience A4: Contractor with work experience of 15 years A5: Chief financial officer (CFO) as the representative of the client/hotel owner with 18 years of work experience A6: Chief Engineer (MEP Engineer) with 11 years of work experience A7: Maintenance Engineer with 12 years of work experience
Case B	
▪ Five star rated hotel with four story building located in Colombo. ▪ North and South wings were refurbished separately. This included upgrading the car park, lift shaft, glass roofs for two restaurants, retractable roof for the dining room, veranda of bar and pool bar, bathroom tiling and glasswork, timberworks for bathroom doors, replacement of kitchen and laundry equipment, maintenance of extra low voltage system and repairing the ceiling of and floor of grand ball room, the balcony areas and modification of MEP services ▪ The project was traditionally procured and the contract type was the re-measurement contract ▪ Contract price was LKR 145,000,000 and final project cost was LKR 147,000,000 ▪ Planned duration of the project was 8 months but the actual duration was 10 months	B1: Project manager with 15 years of work experience B2: Cost consultant with 41 years of work experience B3: Chief architect with 20 years of work experience B4: Contractor with 12 years of work experience B5: Finance Manager as the representative of the client/hotel owner with 28 years of work experience

Case C	
▪ Four star rated hotel with three story building located in Gampaha District. ▪ Refurbishment included upgrading 81 rooms, central air conditioning system, fire alarm system, plumbing works, glass work bathrooms, lighting in corridors, façade maintenance, timber floor repairing, gully and sewerage system modifications, tiling in the kitchen, replacement of kitchen and laundry equipment, maintenance of extra low voltage system, installation of painted glass screens in the front office and modifying the swimming pool ▪ The project was traditionally procured and the contract type was the re-measurement contract ▪ Contract price was LKR 136,500,000 and final project cost was LKR 137,800,000 ▪ Planned duration of the project was 6 months but the actual duration was 9 months	C1: Project manager with 11 years of work experience C2: Cost consultant with 20 years of work experience C3: Designer with 17 years of work experience C4: Contractor with 14 years of work experience C5: Finance Manager as the representative of the client/hotel owner with 22 years of work experience C6: Maintenance Manager with 11 years of work experience and no prior experience in VM

All three case study hotels reportedly conducted refurbishment activities, simultaneous to the regular daily operations in the hotel.

4. RESEARCH FINDINGS

4.1. *CURRENT SITUATION OF REFURBISHMENT PROJECTS IN SRI LANKA*

Capturing insights about the current situation of refurbishment projects was first focussed on the opinions of respondents about refurbishment. Respondent's interpretation on refurbishment was focussed on upgrading and modernising of the building elements and services. Further, explaining the terminology "refurbishment", respondents A1, B2 and C4 were of the view that refurbishment encompasses renovation, retrofitting, modifications, repairing, upgrading, restoration and extension to the existing building to deliver the expected functionality of the building with enhanced performance. According to the explanations of A3 and B1, refurbishment is necessitated for a building after a certain period of time. B1 described; "*a face-lifting of the building done to uplift the building condition after a particular period of time, because the building itself demands repair, modification and upgrade"*.

Moreover, all the respondents confirmed that refurbishment projects in Sri Lanka are mostly conducted for hotel buildings compared to other types of buildings. As pointed out by the respondents, this is mainly because of the fact that Sri Lanka is a famous tourist destination and hotels need to be modified and upgraded more often than the other types of buildings. A1 opined; *"in the Sri Lankan context, tourism is a major source of national income and Sri Lanka is a famous tourist destination. Since, hotels accommodate tourists from various countries, unlike the other types of building facilities, hotel buildings try to maintain their status quo and keep up to date functionality. Refurbishment provides the means for this required updating and modifications"*. In addition to this, since these buildings operate everyday throughout the year they subject to degrading easily and thus means of upgrading and modification are delivered through refurbishment. According to C6; *"since hotels operate 24*7 all year long, building services and the building itself need repairing, scheduled maintenance"*. A7 asserted; "*they operate all day long throughout the year, even at off seasons. So, there's no time to do upgrades or modifications to uplift attraction, but only small scale repairs for survival which we do at our maintenance department level. So, mostly within 15 years, they can't rely on these small repairs and need a face lift"*. The opinions of the respondents suggested that in Sri Lanka, hotels demand a refurbishment within the 10 to 15 years after the building operations are commenced.

4.2. REASONS FOR UNDERTAKING THE REFURBISHMENT FOR THE SELECTED BUILDING

The refurbishment decision is conceived as a result of many attributes. Two major reasons for undertaking refurbishment for the case study buildings were to enhance aesthetic appearance and modernise existing conditions and to compete with rival hotels. Therefore, the selected hotels continue with the existing operation by enhancing through refurbishment.

C5 pointed out; *"to remain competitive, we need upgrades and newest trends and also modifying the existing hotel environment is more important to overcome the challenges we face*". Cases A and B are two of the oldest five star rated hotels in Colombo and thus all the respondents endorsed the view of being competitive. For Case C also, remaining competitive amongst the rival hotels is of utmost importance. Furthermore, as highlighted by the respondents, refurbishment was necessary for all the case study buildings, because major modifications and upgrades have not been done in a while. A1 explained; *"by the time, the refurbishment started, the hotel was 27 years old. From time to time, few small scale renovation and repairing projects had been undertaken to keep the hotel in good standards. In fact, the last renovation was undertaken in 2001"*. In addition to the most significant reasons, respondents of Cases A and B pointed out that since the hotels have long been in operation as five star rated hotels, safeguarding the star rating of the hotel was also a drive for this project. Preserving architectural and archeological value and importance of heritage was a unique reason for the Case B to undertake refurbishment. B3 explained; *"being probably the oldest functioning hotel, we had to ensure that architectural features concerning heritage and cultural aspects attributed to British era and the archaeological value of the hotel remained preserved and intact'*. Among the other reasons, being in the hotel chain of an internationally reputed organisation, maintaining the standards of the parent company was also a drive for the refurbishment for Case A. Therefore, the decision to undertake refurbishment in these buildings were triggered due to many factors.

4.3. CHALLENGES ENCOUNTERED IN THE REFURBISHMENT PROJECTS

The refurbishment projects are deemed to be uncertain and complicated in nature as per the opinions of the respondents. The top most challenges attributed to hotel refurbishment projects, as highlighted by 15 respondents are the budget overruns in superficial designs and construction activities, time overruns for refining designs to cater unanticipated building conditions, limitations to introduce changes to the existing building structures and the interruptions to building occupants due to simultaneous operations. As pointed out by A5, "*the initial designs by the designers exceeded our budget. Reviewing various design options along with budgets consumed a huge time". *A4 also added; "*the project budget based on the designs of lobby finishes with an allowable tax portion of 25% was an underestimated budget"*. Emphasising the limitations on building conditions, C2 claimed; *"we had vague assumptions on the layout duct lines inside the ceiling till we start demolishing. This made us to revisit designs considering limitations of the building services"*. B2 highlighted; "*restrictions to incorporate sustainable designs due to having to conform to archaeological limitations"* in Case B is another example. Challenges due to simultaneous operations in the building as pointed out by B4; *"complaints from guests due to noise in the demolition works especially during our night shift"*. Respondents encountered the issue of lack of as built drawings and site information. Respondents also pointed out about the insufficient safety precautions on site. Among the other challenges, the difficulty of reusing existing material and equipment due to damages in the dismantling and storing is noteworthy. Lack of coordination and communication among project participants was challenging. According to A2, *"because of involvement of few foreign entities and they work in their native countries, the coordination between the parties was a big hurdle in the progress of design"*. C1 also pointed out; *"documentation of tenders with several specialist contractors/sub-contractors was a burden"*. Lack of secured places in the site to store construction equipment was challenging for the project team. A4 stated; *"there were no secured spaces within the hotel premises for us to store most of the procured kitchen and laundry equipment and contractor had to hire warehouse outside the Colombo, and store the equipment"*. In addition, lack of standardised testing and commissioning of the building services and equipment was also noted. B3 pointed out; "*contractor's lack of knowledge about the standard test requirements delayed the completion and smooth handover of the project"*.

All the contractors involved in the project complained that traditional procurement method restrained the contractor's input to design alternatives. Moreover, all the design consultants experienced the challenge of identifying client's requirement properly. Lack of a proper isolation strategy to systematically assign the areas in the building for the refurbishment, while the other areas are in operation was a notable challenge. According to A1, *"in the isolation plan submitted by the lead consultant by identifying the areas that can be allocated for part by part refurbishment, cold room was missing and the project execution plan formulated based on it had to be revised twice".* Lack of supervision during the demolition and construction stage was challengeable for Case B. The respondents of Case C claimed that existing building was subjected to legislative constraints. C3 expressed; *"achieving ISO certifications and being compliant to waste disposal as per municipal regulations made us to limit choosing some material which we initially decided".*

In a summary, all aforementioned challenges can be classified in to two categories as challenges resulted by the existing building and the challenges resulted by the project team.

Table 2: The Classification of the Challenges

Challenges resulted by the existing building	Challenges resulted by the project team
▪ Time overruns due to refining designs to cater unanticipated building conditions ▪ Limitations to introduce changes to the existing building structures ▪ Lack of as built drawings and site information ▪ Lack of secured places in the site to store construction equipment ▪ Existing buildings are subjected to legislative constraints ▪ The difficulty of reusing existing material and equipment due to damages and non-suitability	▪ Budget overruns due to superficial designs and construction activities ▪ Interruptions to building occupants due to simultaneous operations ▪ Lack of coordination, communication of project participants and lack of supervision ▪ Insufficient safety precautions on site ▪ Lack of standardised testing and commissioning of the building services and equipment ▪ Traditional procurement method restrained the contractor's input to design alternatives ▪ Inadequate identification of client's requirements ▪ Absence of a proper isolation strategy to systematically assign the areas in the building for the refurbishment, while the other areas are in operation simultaneously

As per the above classification, majority of the challenges in hotel refurbishment projects in Sri Lanka are resulted by the project team. Although the challenges are termed differently, respondents opined that they are constricted to cost and time overruns, quality impairments, dissatisfaction of hotel customers and lack of sustainability. Therefore, all the respondents endorsed the view that aforementioned challenges contributed adversely in achieving value for money.

5. CONCLUSIONS AND RECOMMENDATIONS

Previous studies have failed to offer a precise definition for refurbishment and certain terminologies are in use interchangeably (Vilches, *et al*., 2017). This study has substantiated that hotel building refurbishment encompasses the terminologies such as renovation, retrofitting, modifications, repairing, upgrading, restoration and extension to the existing buildings. However, present study has suggested that refurbishment of hotel buildings is primarily focussed on upgrading and modifying the elements and services of existing buildings. Athapattu and Gunawardena (2010) highlighted the grooming interest for refurbishment in Sri Lankan hotel sector after the tsunami disaster and also with the growth of tourism. Findings of this study have further corroborated the above claim by revealing that refurbishment of hotel buildings in Sri Lanka are higher compared to other building types, since refurbishment provides avenues to upgrade and modify buildings for enhancing tourist attraction. Findings about the challenges in hotel building refurbishment projects in Sri Lanka are consistent with those of Arain (2005); Egbu *et al*., (2002) and Rahmat and Ali (2010), which suggested that challenges are peculiar to existing buildings. Among such challenges limitations to introduce changes to existing structure, lack of drawings and design information, interruptions to building occupants due to simultaneous operations in the building are prominent in the hotel building refurbishment projects in Sri Lanka. As speculated by many researchers, cost and time overruns seem inevitable for the hotel building refurbishment projects too, because the results of the current study also have pointed out budget overruns and time overruns as two of the top ranked challenges. A possible explanation for this could be the high stakes of hotel industry on cost and time.

Rahmat and Ali (2010) deduced that challenges in refurbishment projects are peculiar to existing buildings and these challenges could result in subverting value for money. The challenges that were identified through the current study, were categorised as challenges resulted by the existing building and the challenges resulted by the project team. It was found that majority of the challenges in hotel refurbishment projects in Sri Lanka are resulted by the project team. It can be further concluded by the present study too that the aforementioned challenges affect adversely in achieving value for money for the refurbishment projects. Moreover, previous studies have claimed that achieving value for money is the final outcome of all construction projects (Emmitt *et al.,* 2005; Martinsuo and Killen, 2014) and value has been interpreted in terms of function, quality, cost and time (Potts & Ankrah, 2013; Yan, 2012). The present study has shown that challenges encountered in hotel building refurbishment projects in Sri Lanka are constricted to cost and time overruns, quality impairments, dissatisfaction of hotel customers and lack of sustainability. These challenges have thus led to reduce value for money. Accordingly, this study has offered some insight in to the necessity of value enhancement approaches in refurbishment projects to overcome the challenges. However previous researchers have also contended that there seems a lack of empirical evidence on the approaches to enhance the value performance of refurbishment projects (Chau *et al.,* 2003). An implication of this study is that further research should therefore concentrate on the investigation on value enhancing approaches to deliver value for money in refurbishment projects by overcoming the challenges.

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COLLABORATION IN THE CONSTRUCTION INDUSTRY: A VIEW FROM THE RAIL SECTOR

Thomas Dowd and Mohan Siriwardena*

Department of Built Environment, Liverpool John Moores University, United Kingdom

ABSTRACT

Need for collaboration in the construction industry has been emphasized constantly in research literature. Several forms of procurement and other approaches were introduced towards promoting collaboration in the past two decades.

This paper reports on an investigation into the nature and extent of collaboration within the rail sector in the UK. Rail sector which is a growth area in the UK's construction industry, and several more projects planned for the near future. A literature review, a questionnaire survey and data analysis were conducted. Literature review identified key elements and dimensions of collaboration. Data analysis conducted following the receipt of the questionnaires revealed varying views between the client and the other parties in terms of the extent and the success of collaboration within the rail sector. The findings have also identified several areas that require further research and development.

Keywords: *Attitudes; Collaboration; Processes; Rail Sector.*

1. INTRODUCTION

Behaviours and attitudes of the construction industry has been heavily scrutinised over the past few decades by many government publications. There has been much discourse over which processes are necessary for to instigate the key changes necessary to improve such attitudes and behaviours. Collaboration as a behavioural approach has received significant attention in this regard.

Rail sector is relatively complex and requires the collaboration of many parties for the effective and efficient construction and maintenance of rail infrastructure. Rail is a growth sector in the UK construction industry. This paper reports a preliminary study on collaboration within the rail sector in the UK. Section 2 of this paper reports the literature review, and section 3 covers the research methodology. Section 4 reports the findings and the discussion of results. Final section provided the concluding remarks.

2. COLLABORATION IN THE CONSTRUCTION INDUSTRY

Wilkinson (2005) states that collaboration is a creative process undertaken by two or more individuals, sharing their collective skills, expertise, understanding and knowledge (information) in an atmosphere of openness, honesty, trust, and mutual respect, to jointly deliver the best solution that meets their common goals.

Several reports and publications in the past have highlighted the need for collaboration in the construction industry. Some of such publications are indicated below.

- Simon Report (1944)

  As one of the early reports in to the construction industry, this report was commissioned to study and critique "The Placing and Management of Building Contracts". The report highlighted the requirement

*Corresponding Author: E-mail - m.l.siriwardena@ljmu.ac.uk

for collaboration in contracts and the early contractor involvement. It is one of the earliest occasions where the need for collaboration was highlighted.

- Latham Report (1994)

  This report was significantly critical of the attitudes and the behaviours of the construction industry. Highlighting the inefficiencies of the construction industry, this report accused the practices which existed at that time as adversarial, ineffective, fragmented, incapable of delivering to its clients, and lacking the respect for its employees. Report encouraged the use of collaborative behaviours and partnering to be adopted by the construction industry.

- Egan Report (1998)

  Egan report further established the need for industry standards and systems to change. Focus on processes was a major recommendation of the report. Report also urged the construction industry to learn lessons from other industries such as manufacturing and service industries.

- Wolstenholme (2009)

  The publication "never waste a good crisis" was written at a time when the UK's construction industry and the wide economy was going through a recession. Urging the industry to use the economic crisis as a way of lessons learnt, it recognised the need to further develop the industry based on the recommendations of Latham and Egan reports. A key recommendation was "to see the bigger picture" and to invest in the long term concepts such as whole life costing, integrated supply chains and invest in the development of people.

- Construction Strategy 2025

  Published in 2013, this report highlighted the fact that lack of collaboration has limited the potential for learning in construction due to the short-term focus of construction teams. It recommended the creation of integrated supply chains with an emphasis on collaboration.

BS11000 – Collaborative Business Relationships is a focus area for Network Rail, the rail infrastructure provider for the UK rail sector (Pope, 2016). In a publication Network Rail states "BS11000 provides us with the strategic framework to develop with our key suppliers, the policies and processes, the culture and behaviours required to establish such collaborative relations and to drive continual improvement" (Network Rail, 2012, p5). Network Rails Collaborative Relationships Management framework which was built on BS11000, identifies eight (8) fundamental subject areas aimed at creating a strong and collaborative relationships along the supply chain as listed below.

1. **Awareness** – Visions, values, leadership and objectives
2. **Knowledge –** Strategy, outcomes, and implementation plan.
3. **Internal Assessment** – Policies, people skills and collaborative maturity
4. **Partner Selection –** Comparability, roles and responsibilities
5. **Working together** – Management systems and processes
6. **Value creation –** Continual improvement processes
7. **Saving together** – Team management monitoring, measurement and behaviours
8. **Exit strategy –** Disengagement triggers and processes

Figure 1: Collaborative Relationships Management (adapted from Network Rail 2012; Pope 2016)

UK Government is keen to ensure that Building Information Modelling (BIM) is used for construction projects, BIM is expected to foster collaboration. Already contractual forms such as Frameworks, and standard forms of contracts such as NEC3 are in use. Under such circumstances, it is pertinent to explore the current status of collaboration within the UK's rail sector.

3. RESEARCH METHODOLOGY

An online questionnaire survey was conducted using SurveyMonkey online software. This tool proved to be an effective way for the participants to complete the survey online instead of having to receive, read, complete and return hardcopies.

The questionnaire was divided into several sections. Section 1 consisted of questions to ascertain the level of experience and exposure of the respondent to the rail sector construction activities. Section 2 included questions aimed at understanding the principle position that the respondent. The section included questions such as "How would you define collaboration". Section 3 was designed to ascertain the collaborative environments / platforms that the respondent has experienced. In this regard care was taken to specifically address technology-enabled environments such as Building Information Modelling (BIM) and Procurement / Contract based approaches such as the use of New Engineering Contract (NEC) or Frameworks. Section 4 was designed to evaluate the effectiveness of the collaboration and challenges.

The survey was sent to 130 professionals within the rail sector. 45 professionals agreed to respond to the survey. There was a wide variety of job roles amongst the participants. These include CEOs, Commercial Directors, Engineering Directors, Project Managers, Quantity Surveyors and several other categories.

4. FINDINGS AND DISCUSSION

The word cloud generated as part of the data analysis indicates that "working together" is the most widely accepted meaning of the term collaboration amongst participants. Other meanings that standout are "common", "shared", "project" and "goals". With regard to the frequency of collaborative working, there is a significant difference in the responses. 38% of the client group state that they work collaboratively, whilst it is 12% for the contractor group. 53% of the client group stated that they sometimes work collaboratively, whilst the respective figure for the contactor group was 84%. In relation to formal training received to develop collaborative work skills, 20% of the respondents indicated that they have not attended a training workshop. Breaking the responses between client, contractor and subcontractor categories, the percentages vastly increases from 15%, 28% to 40% respectively. This is an indication that there is still room for training on collaborative working to be extended to the lower tiers of the supply chain. With regard to leadership in facilitating collaboration, it is clearly evident that the workshops are arranged by the client in most instances. Relatively low level of participation by the subcontractors in a possible sign of low level of supply chain integration as far as the collaboration is concerned.

There was unanimous acceptance that collaboration is predominantly a principle over a process. This is a noteworthy observation as most of the respondents agreed they work in Framework arrangements that are designed to facilitate collaboration. This reinforces the view that collaboration is behavioural and requires attitudinal change. 65% of the respondents stated that they do not use technology for collaboration. The technology referred to in this instance is CEMAR (Contract Event Management and Reporting) for NEC3 contracts. One respondent said they used the programme but "CEMAR does not aid collaboration. It is a contact management tool". In relation to BIM, it is evident from the responses that BIM is not known as a way of collaboration, but as a electronic management tool for transfer of digital information. The government has mandated the use of BIM within the public sector (Department for Business, Innovation and Skills, 2013). However, at the time of the survey, only 36% of the participants are using BIM.

65% of the respondents believed that NEC3 contracts aid the process of collaboration. However it is also noteworthy that 35% disagree, hence the use of NEC3 as a facilitating tool for collaboration requires further attention.

Commercial issues were cited as the key barrier for fostering collaboration. This was supported by 70% of the respondents. Majority of the respondents had a key commercial role within their respective organisations. However, the survey failed to dig deep into this aspect hence require further research.

70% of the respondents believed that collaboration can be fully integrated into the construction industry, However, 30% disagreeing is a noteworthy and requires further attention.

5. CONCLUSIONS

Need for collaboration in the construction industry has been highlighted by successive reports in the UK. At a time when the UK government is actively encouraging the use of BIM and with NEC3 standard form of contract already in use, a preliminary investigation was carried out to explore the nature of collaboration in the UK's rail sector.

It is encouraging to note that 70% of the participants believe that collaboration can be truly integrated into the construction activities of the rail sector. It also highlights the need for continual efforts to improve the status of collaboration in the sector. More effort on training in relation to collaborative environments, aimed at the lower tiers of the supply chain, needs to be focus area for further research and development.

As further research, it is recommended that a larger sample size to be selected, and the data be triangulated using other research techniques such as interviews and observations.

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COLLECTING PRIMARY DATA FOR ACADEMIC RESEARCH IN CRISIS-AFFECTED-REGIONS: CHALLENGES AND RECOMMENDATIONS

Belqais Allali[1*], Udayangani Kulatunga[2], Shahd Salha[3]

[1]School of the Built Environment, University of Salford, United Kingdom

[2]Department of Building Economics, University of Moratuwa, Sri Lanka

[3]Inspector of Education Centre, Sheffield, United Kingdom

ABSTRACT

Collecting primary data for research is one of the most critical stages in the research journey; it is the practical element of the research that requires access to data embedded in fieldwork. If the primary data is collected from a crisis-affected-regions, the fieldwork can generate a high risk to the researcher. The aim of this paper is to investigate the challenges of data collection in crisis-affected-regions. The personal experience of seven different PhD researchers who collected their primary data from crisis-affected-regions are presented and analysed in the paper. The findings suggest that the risks of collecting primary data from crisis-affected-regions can involve different challenges: some of them are related to the researcher, such as a lack of awareness around the aspects of the crisis context. Some other challenges are related to the research study, such as non-clarity of aims and objectives. Also, within the context of study the main challenge of collecting data is a lack of accessibility to data sources and documents. The paper provides different suggestions to improve the practices of collecting primary data from crisis-affected-regions. These are: providing supportive training to researchers who intend to research in crisis-affected-regions, networking with other researchers with the same interests, increased regular meetings with the supervisor, adapting an appropriate approach for collecting the data, and having a risk management plan.

Keywords:*Challenges; Crisis-Affected-Regions; Data Collection; Primary Data; Research Methodology.*

1. INTRODUCTION

Research is a complicated and systematic process of collecting, analysing, and interpreting data information in order to answer questions or enhance the understanding of a particular phenomenon. In order to complete research, the researcher needs to have a plan and the plan should follow up specific stages. Hence, conducting research in itself could be a great challenge, and such challenges can increase in less developed and poor countries where the possibility of political and finical crisis is high (Abreu et al., 2009).

According to Sarkar (2014), there are three main challenges in completing data collection processes in developing countries; namely, gaining the required permission for collecting data, recruiting intended participants and collecting survey information. Owlia and Mirzaei (2014) identified 17 different challenges experienced by researchers in biomedical science research in developing countries. Although, Owlia and Mirzaei (2014) did not specify data collection stages, they included a lack of an integrated strategy for managing research activities and a lack of an adequate holistic approach to collect the data. Litewka (2011) stated that cultural and logistical challenges in Latin America and the Caribbean were obtaining informed consent, which can be a critical issue during the data collection stage, therefore researchers need to understand the context of the research as well as ethical considerations, laws and regulations before starting the research. Rimando et.al. (2015) conducted a qualitative research study to examine the challenges experienced by early career researchers in health sciences during the data collection stage. The findings of the study suggested that 6 main challenges can be experienced by early researchers; namely, location, health literacy and language of

*Corresponding Author: E-mail – belqais2015@gmail.com

the data collection instrument, the duration of data collection, researcher fatigue, and sensitive information. Despite the aforementioned studies, purity of literature has been evident investigating the challenges encountered by social science researchers in crisis-affected-regions. Accordingly, this paper investigates the challenges that may be experienced while collecting primary data in crisis-affected-regions.

2. LITERATURE REVIEW

Collecting primary data for an academic research study in the social sciences is a major stage of the research process. Blankenship (2010) identified the research process as a project that consists of a set of decisions that should be made from the start until the end to complete the research successfully. Therefore, these decisions are the basis that allows the researcher to undertake any research study in an efficient manner (Blankenship, 2010). In addition, Arthur and Hancock (2009) suggested that the research can be considered as a process of systematic investigation for the purpose of adding a contribution to knowledge around a certain subject area. Therefore, this meaning can be categorised into three main areas. Firstly, the investigation is planned and carried out systematically, by conducting research in a specific subject that leads to contribute to new knowledge, as well as increasing the researcher's understanding of the studied phenomenon. The research has to be carried out in stages in order to achieve the research aim and objectives in a systematic manner (Arthur & Hancock, 2009). Arthur and Hancock (2009) suggested that by following the research stages in a proper manner, the originality of the studied research would be achieved. Figure 1 below shows the main research stages.

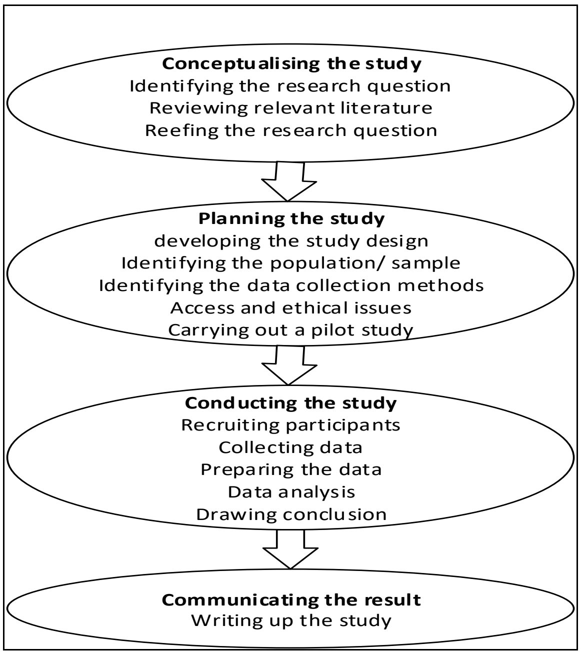

Figure 1: An 'Idealized' Perspective of the Research Process (Adapted from: Arthur and Hancock, 2009)

In the same vein, Blankenship (2010) added that research has steps, which are mainly related to the focus of the studied phenomenon, collecting the data to be analysed, coming up with conclusions, and ultimately evaluating the findings. These stages have been summarised in Table 1.

It can be seen that in Figure 1 the stages are categorised into four main categories; namely, conceptualising the study, planning the study, conducting the study, and communicating the results; under each category a set of steps is to be followed as shown in Figure 1. However, Table 1 shows that the research can be undertaken by following eight steps that have been identified in Table 1 regardless of the research type and orientation. Although, all these steps are important to complete any research in social science successfully, the data collection stage is considered as the most critical stage because the fundamental requirement of the research being valid and reliable is based on whether the data collection process was appropriate for the research that has been undertaken (Miles *et al*., 1994; Gerrish and Lacey, 2010). In the same vein, Keraminiyage (2009) highlighted that in order to achieve the research validity a proper research design, research approach, and data collection techniques should be considered.

Table 1: Steps of the Research Process (Blankenship, 2010)

Step	Example
1. Identify the problem or question	Childhood obesity
2. Review the literature	Look for similar studies that have been conducted
3. Clarity the problem-specifically identify the purpose of the study	The purpose of the study is to determine if walking 10,000 steps a day for three days a week improve a person's health
4. Clearly define terms and concepts	This is done so that the readers understand exactly what each term means
5. Define the population	Children who are 10 to 12 years old
6. Develop the instrumentation plan	Data will be collected on the variables at the beginning of the program and at the conclusion of the study
7. Collect data	Collect the data on the specified variables at the first and last sessions of the program
8. Analyze the data	Compare data gathered from each participant. The first measurements are compared to the second measurements to see if there is a difference. Report the results and the differences if there is any

Hoskins and White (2013); Dearnley (2005); Doody and Noonan (2013) stated that a lack of experience and skills in terms of conducting interviews and accessing qualitative data, is a crucial issue because a lack of adequate data will influence the validity and the credibility of the research.

As the literature review was conducted for this study, it became apparent that there is a dearth of research studies investigating the challenges that researchers face conducting research in crisis-affected-regions. The reality is that this gap is present not only for the focus of the topic, but also on the understanding of what the concept of crisis means or how the concept has been conceptualised.

Linguistically, the Oxford online dictionary identifies the word crisis as "a noun which means either "a time of intense difficulty or danger" or "a time when a difficult or important decision must be made" (Dictionary OED, 2017). Furthermore, Al-Dahash *et al.* (2016) state that crises "are generally associated with a system, organisation, and group of people or individuals. The key features of a crisis are uniqueness, danger, being troublesome or causing damage, being unexpected, and usually emotional". These meanings suggest that a country which experiences crisis is performing in difficult situations where people are not able to act as they normally would. According to Ford *et.al*. (2009), recently crises have increased in the world and affected many countries, which has impacted negatively on the daily life of people. They added that research becomes more complicated when it is conducted in crisis-affected-regions. Wood (2006) said that "The approval of and adherence to protocols is of course not sufficient to ensure adequate ethical judgment; such protocols cannot anticipate the many dilemmas other than issues of informed consent and data security that arise in the course of research", particularly in crisis-affected-regions. Campbell (2017) and Goodhand (2000) identified the challenges experienced by researchers in crisis-affected-regions as obtaining informed consent, researcher security, and suggested more training to be provided.

Having synthesised the literature, the next section discusses the research methodology adopted for the study.

3. METHODOLOGY

To understand the nature of the interaction between the studied social phenomenon (the challenges that can be faced while conducting research in crisis-affected-regions) and the related theory required the following methodology. An examination of the experiences of social science researchers during the data collection stage of their study was conducted. Hence, in terms of the philosophical stance of this research, an interpretivist assumption has been taken, because this research tends to understand a phenomenon from the perspective of the individuals who interact with the phenomenon and their experiences, opinions, and interpretations. Accordingly, this investigation of the real situation is based on a pure qualitative approach in order to obtain the real situation in depth and provide rich insights into people's views. Therefore, based on the fact that this research falls under a qualitative approach, an understanding of the studied phenomenon will occur once the meanings and opinions of the studied phenomenon have been collected from the participants. Since this research takes an interpretivistic stance, an ethnography strategy has been selected. Interestingly, O'reilly (2012) considered ethnography as a theory of practice which is the result of the human interaction through their experiences in their everyday life. Furthermore, LeCompte and Schensul (1999) highlighted that conducting ethnography is effective in terms of describing the problem in a specific and local population;

understanding in depth the causes and therefore, the prevention of a particular issue. Hence, ethnography has been chosen because the focus of this research is on investigating, in-depth, the experiences which researchers face during collecting data in crisis-affected-regions.

In terms of data collection techniques, unstructured face-to-face interviews have been conducted in this research. Wildemuth (2016) argued that the unstructured interviews method is commonly used in ethnographic studies in order to examine people's life experience. And it can be the same concept of informal conversational interview, in-depth interview, non-standardised interview, and ethnographic interview (Wildemuth, 2016). Such interviews are typically directed by the informant rather than by a set of questions (Longhurst, 2003; Wethington & McDarby 2016). Furthermore, Punch (2013) explained unstructured interviews as a way to understand the complex behaviour of people without taking or supposing any prior categorisation while they are talking about their experience in a specific phenomenon in a period of time.

In terms of the participants, researchers who have conducted their data collection in crisis-affected-regions have been considered. The implications of the research have been fully explained to potential participants, as some may not feel comfortable with this level of intervention into their experience of life. In terms of sample size, Kumar (2011) stated that the selected size of the sample in qualitative research is less important than in quantitative research as qualitative research is more about quality rather than quantity. Also, Francis *et al*. (2010) suggested that “In interviews studies, sample size is often justified by interviewing participants until reaching data saturation”. That means that interviews will be conducted until no new ideas emerge, in other words, when data saturation is achieved.

In this study, the samples were purposely selected because the nature of the studied topic required participants to ‘open up’ and to have the desire to cooperate. Additionally, in qualitative research the decision made on sample size is complex in nature; the researcher has to be considered when choosing the sample size in such a type of research. The interviews were conducted in Arabic; thus translation was required. Face-to-face un-structured interviews were conducted with 7 participants who have undertaken research in a crisis-affected-region. It is vital to mention that the code N (followed by a number) refers to the interview from which the evidence quotations were extracted, thus indicating from which interviews the quotation was taken from out of the 1–7 interviews. For instance, if a quotation was extracted from interview 2 then the presentation in the text will be such: “the quotation"(N -2).

4. FINDINGS

It was found in this study that the challenges related to data collection are not limited to the stage itself, rather to the whole process of the research, among three different categories, which are: before collecting the data, during collecting the data and after collecting the data. Among all three categories, three different elements in interaction constantly are: the researcher who needs to interact with the context to answer the aims of the research.

4.1. BEFORE STARTING THE DATA COLLECTION

As can be seen from Figure 2, researchers in social science might face challenges that influence collecting primary data from the beginning of the research. The challenge might come from the topic of the research which can be risky (See Figure 2). One of the participants stated *that "My topic itself is risky … I am studying the security companies in my home country. As you know not all topics have the same level of risk, some topics are riskier than others (laughing). Mine is one of those highly risky topics"* (N-2), and when she was asked what she did to control such risk, her response was "*talking to other researchers in my topic area helped me gain a deeper understanding to my topic. I was able to identify the possible risks; knowledge is power*" (N-2). Another researcher argued *"social science research is risky itself because your data is dependent on the participants, who in my case are living in a war-zone"* (N-5), and when she was asked how she controlled the risk she answered "*We are talking about social science research in crisis zones, control is very much related to knowing what is happening in your context before you go. If you do not know what the crisis is and the detail about the war zone you will be at high risk*" (N-5). From the literature, Wang *et al,* (2016) defined crisis areas as the places where people live in an environment considered to have high uncertainty and risk which is accrued by a series of adverse events that are commonly understood as crises or disasters.

Interestingly, one of the participants was asked if she received any training, the researcher said "*I am an independent researcher doing research to develop educational practices for children. I have done a lot of research before, I mean I knew what I was doing in terms of collecting the data with well-skilled researchers, but I think training new researchers is very important, and I would suggest training courses for researchers who conducting a research in crisis regions in order to learn more about how to complete a PhD successfully*" (N-6). In this vein, Zamoum (2013) argued that managing in a crisis needs a variety of skills and experience before being involved in such a situation. Furthermore, planning is one of the most important elements that should be undertaken and considered with crisis management. Thus, Zamoum (2013) added that in order to have an achievable plan, three main issues should be undertaken, those issues are: the nature of the crisis should be defined and understood; seeking the proper strategy to manage the crisis; and developing different ways of communication.

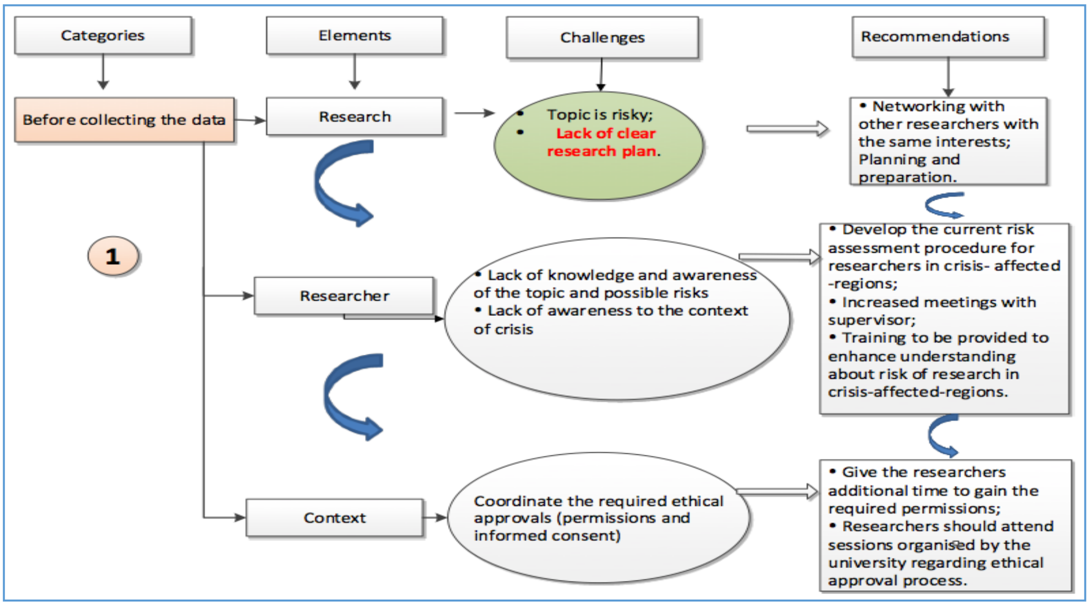

Figure 2: Before Collecting the Data: Cycle of Challenges Associated with Recommendations

In terms of the ethical approval process, a PhD researcher argued "*I will be very honest with you, some of supervisors are unaware about what is happing there, I mean in our war countries. Even the research office all they are worried about is bureaucratic procedures of ethical approval (silent) they do not really care*" (N-7). Moreover, another researcher suggested on this matter "*I think a different set of rules and ethical approval should be made for researchers who are planning to conduct research in crisis zones*" (N-1). From the perspective of the literature, the issue of gaining ethical approval for non-medical research was addressed by Cairns and Gilhooly (2011) who stated that gaining ethical approval can be a long journey of 16 months. Lowton (2016) added that "*in the UK at least, the bureaucracy of ethics review and the charge of 'ethics creep' has led some academics to decide not to conduct the projects they believe in passionately, since they perceive that approval will not be forthcoming or be too time consuming to obtain*" So, the bureaucracy in obtaining ethical approval for social science research influences the motivation of the researcher who might dispose of a great chance to conduct creative research. The influence would be greater on the researcher who intends to carry out research in crisis-affected-regions and the topic itself could be risky, combined with a lack of experience in research alongside other challenges international researchers in the UK are experiencing. Due to the time taken for the ethical approval process (due to the aforementioned bureaucratic nature), the researchers need to plan it carefully, keeping time for obtaining the relevant documents from the case study organisations (if needed), and for the extensive time taken to obtain the ethical approval from the university. Therefore, researchers are strongly advised to attend training sessions that explain how to apply for ethical approval which are regularly organised by universities.

Planning and preparation before the data collection stage is vital before going to the fieldwork to conduct research, especially in crisis areas, one of the researchers said "*I can say that (before the data collection journey) or the 'Planning stage' is a very important step that should be undertaken, especially for choosing the proper data collection method*". Also, thinking of the issues that are related to travelling to the study area such as expenses and the security situation (N-4). For example, before the data collection, researchers need to plan the sequence of data collection - whether to do it sequentially or parallel, based on the context/accessibility. A researcher conducting research in crisis-affected-regions may decide to travel several times to implement different data collection techniques (questionnaire survey, interviews), yet this might not be practical due to security reasons. So researchers should have a plan B in case they are not able to travel again to the studied context, so it is very important to keep in touch with the participants and maintain the connections with them in order to continue collecting the data as well as reaching the validation stage.

Other findings suggested that the purpose of the data collection is mainly based on the researcher's motivation, the aim of the research study, and the accessibility to the studied context. In fact, the research that explores certain phenomenon in a settled context is unlike a research aim with investigation of issues in a crisis area, as this directly influences the data accessibility. Interestingly, the challenges identified during the time before data collection are all linked to each other. Therefore, it is important to have training, planning, and communication (networking) before starting collecting the data.

4.2. DURING COLLECTING DATA

When it comes to the stage where the researcher starts collecting data (See Figure 3), the level of anxiety will increase, "*how will I know that I have collected enough data, I was very worried, all the time worried*" (N-7). Another researcher said "*you will ask yourself every minute if you collected enough information and you know that you might not be able to come again to redo your research or to collect more data, do you know how frustrated I was, I was not able to sleep at night*" (N-2). Another researcher who conducted a research in crisis region said "*I had to leave my house early every day in the morning, there was a lack of petrol and the security state of the country was very bad. I read all the prayers I knew before leaving my house, I was motivating myself I did not want to give up on my research. (Silent), yes I did not want to fail*"(N-1).

The issue of time was also raised during the interviews, collecting the research on time is a crucial point, especially for those researchers who are sponsored. Again, motivation is the principle driving the researcher to complete the research in a certain timeframe. Motivation is very much related to the attitudes of the researcher and to what extent they are ready and prepared psychologically. From the point view of the literature, Wang *et al.* (2016) stated that individuals should maintain a positive attitude and stay strong throughout crisis-affected-regions, and they categorised crisis management strategies into three main categories, which are: fighting, compromising, and avoiding. For instance, in the fighting category, Wang *et al*. (2016) suggested that a strategy can be enhancing the communication with professional networks, keeping going, and being motivated while resolving issues. Furthermore, the strategies in the compromising category can be keep learning and benefiting from others' experiences, being flexible and adapting the reality. In the avoiding category, Wang *et al*. (2016) mentioned that the main strategy is seeking help from a higher authority when a crisis event has occurred.

Also, issues such as receiving support from the academic environment, and the positive interaction with the participants. Accordingly, N-1 pointed out that motivation to carry out my research came from the encouragement that I received from my supervisor as she directs me to the safer side, unlike other supervisors who guide their students without considering the situation. So her support made me more motivated and confident. Also, the interaction of the interviewees and their desire to share their experience and knowledge was helpful. Moreover, motivation can be the reason behind taking a risk while collecting the data as N-1, who is female, added: I remember that one of my tough experiences was that I had to do one of the interviews on a Saturday, which was the weekend, and the institution was empty and I was frightened, however, I had no other chance, it was important to collect information from this specific person who was only available during the weekend (N-1).

In terms of the participants, it is important to collect enough data to reach a valid number in order to achieve a valid result, regardless of the research type - whether qualitative or quantitative research. One of the interviewees said that I had arranged to meet with my friends who have experience in the studied field, and through them I have reached the proper sample numbers of the questionnaires. Also, interpersonal relationships are one of the most important factors, especially in an unsettled context like Libya (N-2). He added that I decided to distribute electronic questionnaires and this decision was made based on the fact that even though the process of distributing the questionnaires took longer, it was much better than travelling to Libya for data collection, as it is in a crisis situation (N-2). One of the interviewees mentioned the decision of selecting the data collection methods was influenced by the studied context, mainly where the crisis is recorded. In this vein, N-3 said "*I totally believed that the studied context highly influenced selecting data collection methods, especially in regards to the accessibility as each step has got a limitation. As a researcher, I must have a clear plan how I would be able to go back to my participants as needed. In my case I asked all the participants to provide me with different contact information*". Therefore, in terms of the accessibility to the context and creating the network connections, the researcher who undertakes research in crisis areas should be aware before collecting the data of the situation and have a strategy from the early stages in order to accomplish the research aim and objectives. Accordingly, Cohn *et al*. (2000) and Speth and Zinn (2008) all agreed that efficient crisis management needs a high acceptance of uncertainty and ambiguity with high self-awareness. Hence, it requires high morale and awareness from researchers who conduct research in crisis areas.

According to the findings of this research study, considering the attitudes in terms of psychological acceptance is essential. Berinato and Allen (2010) defined psychological attitudes as how individuals make sense and seek meaning out of crisis and take action towards resolving the situation. In addition, Comer (2010) added that psychological attitude *"acceptance will allow them to anticipate and get ready for worst-case scenarios; to understand risk and take it seriously, rather than to underestimate and dismiss it; and to weigh the interests of all who would be affected by the repercussions of a crisis*". Furthermore, from the suggested findings, conducting research in crisis-affected-regions requires the flexibility to adapt, which is linked mainly with the understanding of the meaning of crisis in order to be able to deal with such a situation and achieve the aim of the studied context. Accordingly, Comer (2010) identified crisis as "*a low-probability high-consequence event*". Furthermore, Comer (2010) extended the concept of crisis into two categories, where the first concept of crisis underlines preparedness, the other one emphasizes responsiveness. It seems that during the data collection stage, great pressure is on the researcher who should know how to control the risk, and seek the required support to keep the level of motivation up. Being prepared and trained and creating a well-established communication level with the supervisor, as well as with participants, to control the possible risks which might appear after collecting the data, is also essential.

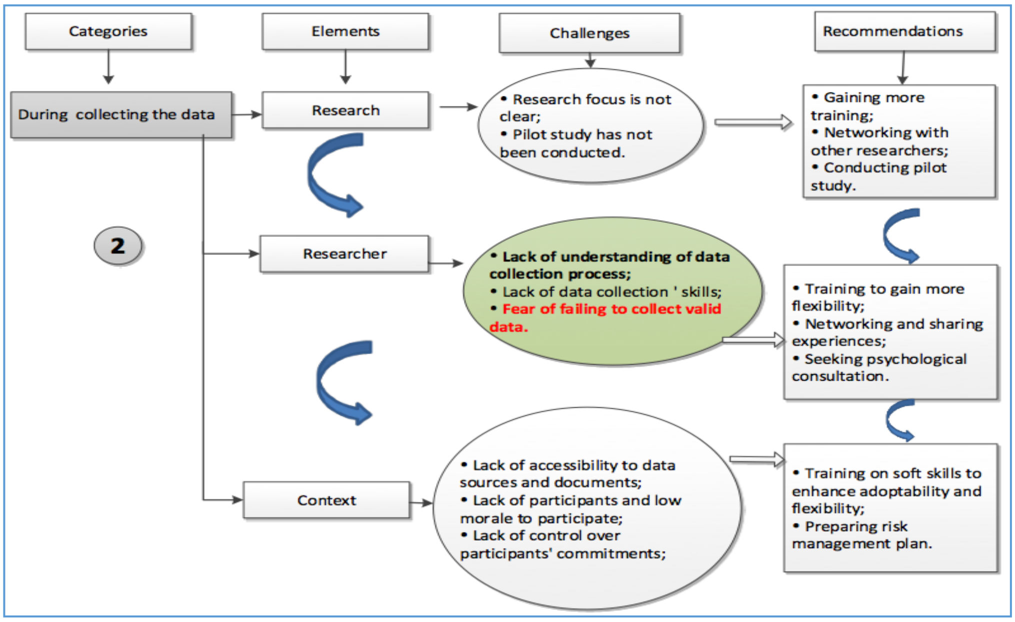

Figure 3: During the Data Collection: Cycle of Challenges Associated with Recommendations

4.3. *AFTER THE DATA COLLECTION*

After collecting the data (See Figure 4), it is very important that the researcher is continuously motivated as well as satisfied with the results. Accordingly, one of the interviewees mentioned that I was satisfied with my collected data so far, and I only faced a difficulty in the translation to find a proper translation for the terminology. For example, with the term (constant explosions), I faced difficulties in finding the right meaning for this term (N-1). Furthermore, from the findings it has been emphasised that being motivated before, during, and after the data collection process is vital especially for researchers who carry out research in crisis-affected-regions. N-7 agreed and says "*I remember that from when I started my PhD until I finished I was persistent and motivated. [Silent] Although I had many challenges related to personal challenges, for example, family* *responsibility, financial issues, etc or related to the studied context in terms of a risky situation in collecting data and the accessibility to data, as well as the arrangements with the participants, my motivation to continue the research and reach the goal was high*". Interestingly, from the findings it has been illustrated that the supervisor can play a positive or negative role in keeping the motivation continuous, especially when undertaking research in crisis-affected-regions. In this vein, N-1 said I would like to insist that from my experience the most important thing is to be continuously motivated before, during, and after data collection, it was the encouragement that I received from my supervisor as she directed me throughout the study. So her support made me more motivated and confident. Also, the interaction of the interviewees and their desire to share their experience and knowledge was helpful. Interpersonal relationships are very important in this case. Also being diplomatic and flexible in the conversation from both sides.

Furthermore, achievement of richness and valid data is the target of any successful research study, from the analysis of the information received in the interviews. In the last category, which is after the data collection journey, the interview findings suggested that valid data achievement is one of the most important challenges in conducting research in crisis-affected-regions. Accordingly, the researcher who conducts research in crisis-affected-areas, after accomplishing the data collection stage, should feel satisfied with the collected data and believe that the data is rich and valid, and have answered the research questions. One of the interviewees said I believe that collecting rich data is not affected by the crisis, rather the chosen participants and their willingness and desire to share their experiences and give more information, which is related to the studied focus and therefore will help the researcher to gain rich data in order to answer the research questions effectively (N-3).

The main issue that has been highlighted within this stage was the level of achievement that the researcher attains while conducting research in crisis-affected-regions, in terms of obtaining richness and validity of the data, and to what extent the researcher can learn from this critical experience. Comer (2010) suggested that individuals who are working in crisis situations should be allowed to translate the task that should be undertaken in crisis arears into meaningful knowledge, skills, and abilities. Regardless of the type of tasks to be done, this research focuses on the challenges that may be faced when the researcher conducts a research study in crisis areas and therefore there are lessons that can be learned from this critical experience. Comer (2010) mentioned that people who are working on or dealing with crisis events should be thinking of what lessons can be taken. Gottschalk (2000) stated that recognizing the need to open and maintain communication channels with others is one of the most important lessons to be learned especially where crisis events are recorded, as well as building up networking and interpersonal relationships. Also, increasing the level of awareness where the crisis is recorded is crucial, much more so than in a settled context.

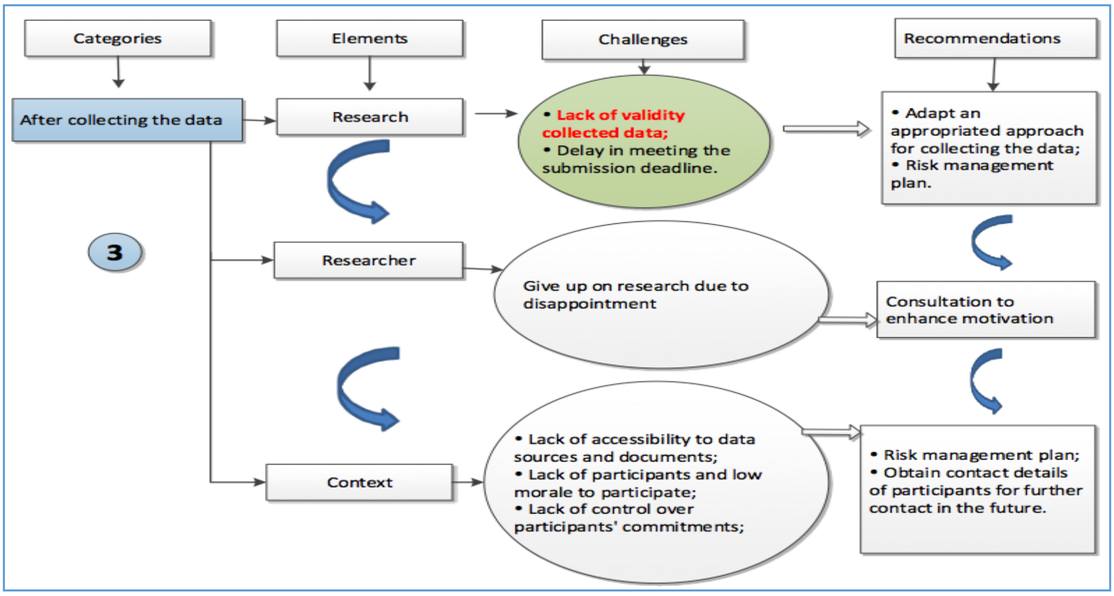

Figure 4: After the Data Collection: Cycle of Challenges Associated with Recommendations

According to Vose and Cervellini (1938, p. 40) "some of the problems of scientific research in developing countries, such as creating an increased pool of trained people, providing more resources and strengthening the whole national infrastructure, can only be solved through time". However, such problems can be more complicated in countries that experience conflict or war, in other words, countries in crisis situations.

Having discussed the findings that were collected from seven participants who conducted research in crisis-affected-regions. Figures 2, 3, and 4 illustrate the interaction among all three categories (before, during, and after collecting the data) including the research elements, challenges, and recommendations. For instance, if the researcher has an unclear research plan before collecting the data towards deciding upon which data collection instruments that will be used, this will affect the data collection during stage in terms of gaining richness and valid data. Consequently, this will have an impact on the reliability and validity of the conducted research.

5. CONCLUSIONS

To sum up, academic research can be defined as a systematic approach, which consists of logical processes that should be followed to meet the research aim and objectives. While all the research stages are significant, collecting primary data is more critical because of the research validity and reliability. As mentioned above, achieving the validity and reliability links strongly within the proper choice of data collection methods and techniques. Accordingly, this paper has discussed the challenges that researchers face while collecting primary data for academic research purposes in crisis-affected-regions.

As a result of conducting this research, the findings suggested that there are challenges related to the data collection stage, including three different categories, namely: before collecting the data, during collecting the data and after collecting the data. With all the categories, three different elements are linked interacted constantly; those are: research, researcher, and context. As a result, the authors identified a set of challenges associated by a set of recommendations. Therefore, some of challenges are related to the researcher, such as a lack of understanding of the data collection process. Some other challenges are related to research, such as a lack of validity in the collected data. Also, within the context of study, the main challenge of collecting data from crisis-affected-regions has been revealed as a lack of accessibility to data sources. The paper provides different recommendations to improve the practices of collecting primary data for researchers collecting data from crisis-affected-regions, such as: providing supportive training to those who intend to research in crisis-affected-regions, networking with other researchers with the same interests, increasing the number and frequency of meetings with the supervisor, adopting an appropriate approach for collecting the data, and having a risk management plan.

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COMPATIBILITY OF BIM BASED BOQ FOR SRI LANKAN CONSTRUCTION INDUSTRY

M.W. Thiwanka Sandaruwan[1] and H.S. Jayasena[2]

[1]Department of the Built Environment, Liverpool John Moores University, United Kingdom

[2]Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Being a key contributor to the Sri Lankan GDP, it is paramount for the construction industry to maximize the productivity, accuracy and efficiency. In order achieve this, it should advance with adoption of modern technologies, computer software and concepts. Many construction industries around the world are getting benefits by implementing Building Information Modelling (BIM) in their projects. BIM has made significant improvement in productivity, accuracy and efficiency. BIM can significantly automate the BOQ preparation process primarily through automated Quantity Take-off from BIM models. The process can deliver accurate quantities as per the model, but these quantities may deviate from quantities measured manually following a Standard Method of Measurement (SMM). But, not implementing automated BOQ process would become wasteful in an effort to implement BIM seeking for its benefits. This research was conducted with the aim of identifying the acceptability of the BIM based BOQ for the Sri Lankan construction industry. A literature survey was first carried out to identify the features of BIM based BOQ. A desk study was followed to identify the deviations of BIM based BOQ from the Sri Lankan conventional BOQ. Based on collected details through these two methods contextualized semi structured interview sessions were conducted to identify the acceptability of deviations in BIM based BOQ for the Sri Lankan construction industry. From the findings through the analysis of collected data, it can be concluded that BIM based BOQ are acceptable to the Sri Lankan construction industry.

Keywords:*Bills of Quantities; Building Information Modelling (BIM); Construction; Pricing; Sri Lanka.*

1. INTRODUCTION

Among the industries in the world, construction industry is one among those having long existence in history. With the development of the other industries in the world, the construction industry also has developed, yet the relative improvement in terms of accuracy, efficiency and productivity is often questioned. To address issues of accuracy, efficiency and productivity, many attempts have been taken; and introduction Building Information Modelling, or BIM as it is widely known, is often identified as a major leap in this endeavor. With incorporation of BIM concept, many new tools, especially the software tools were developed to offer significantly improved accuracy and efficiency to the information aspects of construction industry. Automated quantities from BIM is one of the BIM benefit highly talked about even in Sri Lankan context (Mayouran & Jayasena, 2013).

It is generally acknowledged that with invent of BIM, current construction industry is facing a paradigm shift (Arayici, 2012). BIM automation can deliver highly accurate quantities as per the model, i.e. it offers exact modeled quantities. Industry has had practices of measuring quantities manually following standard methods of measurement (SMMs). Quantities so measured shall deviate from modelled quantities primarily due to several rules of measurement in those SMMs. As the industry is used to price construction works following these rules, it brings the question if the industry capable of adopting the change from the pricing point of view. Since the problem is contextual that each country has its own SMMs, a study was done on Sri Lankan context and presented in this paper.

*Corresponding Author: E-mail – thiwanka.s@asia.com

2. LITERATURE REVIEW

2.1. BUILDING INFORMATION MODELING (BIM)

Building Information Modeling (BIM) is an intelligent 3D model-based process, which was introduced to the Architectural, Engineering and Construction (ACE) industries. BIM is one of the solutions to most of the problems in construction industry (Haron, 2009). BIM is one of the most valuable concepts which was introduced to the construction industry in 21st century. BIM is not only a software and it's a combination of both technology and a process. The technology part helps to stakeholders to visualize the building prior to its construction starts (Nagalingam et al., 2013). BIM concept was started with the development of computer-aided designs in 1970s. From the 1970s to today BIM had following important benchmarks (Jimenez, 2003-2017):

- 1970 – Invention of Computer-aided design (CAD)
- 1984 – Released the first commercial version of ArchiCAD

"Building Information Modelling (BIM) is a new paradigm in the thriving Sustainable construction industry. BIM has a great potential for integration into construction projects life cycle" (Nagalingam *et al.,* 2013). BIM concept started with the invention of the 2D, 3D computer aided design (CAD) in 1970. With the first replacement of the commercial ArchiCAD software in 1986, BIM became a fourth dimension "4D" with adding time factor to the construction designs.

After comparatively a long time, BIM added 5D concept to the designs with the release of Autodesk Revit in 2000. Autodesk Revit could be able to allow a cost associate to the construction designs. The First Autodesk Revit project was construction of freedom tower in New York". (Jimenez, 2003-2017).

2.2. BIM FOR STAKEHOLDERS

Building Information Modelling (BIM) has been successful to change the traditional methods in the construction industry and it has been able to replace the traditional construction planning techniques with the new technologies. There are so many features on the BIM concept that can be implemented to the current construction industry. Building Information Modeling (BIM) can be used in the professions of Architecture / MEP Designers, Estimators / Commercial Managers, Project Managers and Civil / MEP Engineers. Among the above professions in a construction industry BIM offers valuable uses for Estimators and Commercial mangers.

2.3. ESTIMATORS / COMMERCIAL MANAGERS

In the pre contract stage the quantity surveyor is known as an estimator and at the post contract stage the quantity surveyor is known as commercial manager. The quantity surveyor can use the BIM concept at each stage of the project. The role of the quantity surveyor in BIM based environment, "As of quantity surveyor job descriptions, the quantity surveyor is responsible for preparation of preliminary estimates for the projects and the feasibility study cost plan to submit to the client (Olatunji *et al.,* 2009).

2.4. BOQ WITH BIM ENVIRONMENT

Traditional BOQs have been prepared manually, but with the development of the current construction industry, productivity and efficiency has taken a very important place. Nadeem et al. (2015) has done a research on current requirements of BIM based BOQs in the industry to increase the product efficiency and the accuracy. According to his explanations, "with the features of the BIM software, it provides 3D visualization to extract quantities and to get a full idea about the building… [and show that] these things help to develop a cost estimate using related BIM software" (Nadeem *et al.,* 2015). The BIM concept, it is very easy for the contractor's quantity surveyor to take off the quantities from giving drawings and specifications (Nadeem *et al.,* 2015).

2.5. *FEATURES OF BIM BASED BOQ*

Identifying the features of BIM based BOQ is a one of the objectives in this research. This research was designed to do a literature survey to identify the features of BIM based BOQ. Following features were found throughout a good literature survey.

2.5.1. MODEL INFORMATION EXCHANGE

File types or formats of the documents support the BIM tools. The BIM software is capable to work with universal file formats such as IFC / DWG / PDF. In the literature survey of this research, the researchers identified model information exchange as a feature of a BIM based BOQ.

Model information exchange is very important to work in the modern construction industry. BIM based BOQ can be viewed in various types of file with this feature the parties who interested with the of a construction project they can view the BOQ with application what is available with them. BIM model has a feature to export these documents in various formats.

2.5.2. 3D VISUALIZATION

BIM software is capable to build 3D models. 3D modelling is a good way to clash detections. It is very important to identify the clashes in a building before it builds and it can help to avoid the unnecessary design changes as well as the cost revisions. 3D visualization is a great benefit in BIM based BOQ, compared to the conventional BOQ in the Sri Lankan practice, there may be some clashes in the architect design prior to the estimating stages. These clashes should be clearly understood because, if such a situation happened at the construction stage, it will be changing the whole design and also the BOQ work item of the project. Therefore, having a facility of 3D visualization to the BOQ preparation is very important.

2.5.3. RELIABILITY OF INFORMATION PRODUCTION

BIM software is capable to extract and transfer the information and also BIM is a good tool to generate more information related to the projects. For an estimator information are the valuable things in making estimates for a construction project. BIM is a good information source to make BOQ and it consists with more information needed for an estimator.

2.5.4. CUSTOMISATION OF FORMATS

BIM is capable to customize its reports formats. The BIM user can change the report formats as estimator's requirements. In practicing construction projects, there are some requirements in customizing formats. BIM has an ability of editing and changing the formats of its produce.

2.5.5. AUTOMATED QUANTITY TAKE OFF (QTO)

Quantity Take Off task is a major task in any kind of construction project because of the measurement part of a construction project should be accurate and unfailing (Mayouran & Jayasena, 2013). Quantity Take Off task is generally done by quantity surveyors / estimators manually or with the help of software packages such as Computer Aided Design (CAD) or most of the Autodesk projects (Mayouran & Jayasena, 2013). According to the explanation of professor Song Wu it takes a long time to extract quantities from an AutoCAD drawing. Further to his explorations most of the software was developed to minimize the time of skilled people which can survey in the process of and skill people consume in the process of QTO (Quantity Take Off). (Wu *et al.,* 2014). The BIM concept has developed to facilitate the cost estimates in the construction industry. The BIM model is a 3D object, which consists geometrical information and BIM gives opportunity to automatically extract the volumes and the areas of the BIM model (Wu *et al.,* 2014).

3. RESEARCH METHODOLOGY

To identify the acceptability of BIM based BOQ for Sri Lankan construction industry this research was designed to be conducted using following data collecting methods.

- Literature survey

- Desk study
- Semi structured interviews

In this research, qualitative research was identified as the research approaches because of the study aimed in-depth of understanding the compatibility of BIM based BOQ for Sri Lankan construction industry, rather than generalized application of it.

Through a literature survey, it's possible to identify what are the previous researches have been done in a particular subject are. To achieve the first objective of the research "Identify the features of BIM based Bill of Quantities**"** literature survey was conducted by using journal articles which are related to this field of study. To achieve the Second objective of the research "Identify the deviations of BIM based BOQ from conventional BOQ in Sri Lanka**"** a desk study was done by referring the Standard Method of Measurement, SLS 573, along with a popular BIM authoring system Autodesk Revit. SLS 573 is the Sri Lankan standard of measurement. In the desk study, the researchers identified some deviations of BIM based BOQs compared to the Conventional BOQs. At the end of desk study six numbers of sample deviations representing key areas of deviations identified were developed to be use at expert interviews.

To achieve the third objective of this research which is "Identify the acceptability of deviations for the Sri Lankan Industry" Six interview sessions with six Quantity Surveyors who are well experienced professionals in the field was conducted.

3.1. RESEARCH SAMPLE

To collect the data to conduct the research and identify the acceptability of deviations for the Sri Lankan Industry, the research sample was selected as follows.

Table 1: Research Sample Size

No	Category	No. of Interviews
01.	Pre-Contract Quantity Surveyors	02 Quantity Surveyors
02.	Post-Contract Quantity Surveyors	02 Quantity Surveyors
03.	Consultant Quantity Surveyors	02 Quantity Surveyors

Sample deviations were presented to the experts requesting their feedback on applicability and acceptability of the changes to the Sri Lankan construction industry from the pricing point of view.

3.2. FINDINGS OF DESK STUDY

The desk study session was conducted in order to identify the deviations of BIM based BOQ from conventional BOQ in Sri Lankan construction industry. During the desk study researchers were able to find out two categories of deviations between BIM based BOQ and the conventional BOQ in Sri Lankan construction industry. These deviations are Quantity adjustments and deviation in element definitions are the key findings of desk study.

3.2.1. QUANTITY ADJUSTMENTS

By referring to the SLS 573 document, researchers could identify some quantity adjustments in BIM based BOQ compared to the conventional BOQ in Sri Lankan construction industry. Automated quantity takes off using the BIM tool is an advanced process, but according to the desk study of the research, it could find some quantity adjustment in automated quantity take off. These quantity adjustments can be found in taking off quantities in surface within minor voids. According to the SLS 573, the measurement rule is to measure with these minor voids, but according to the automated quantity take off with BIM software, all types of voids deducted by the software.

E.g. 01:

According to the SLS 573, measuring of quantities in formwork, there are no deductions made for deductions for voids less than 0.5 m^2.

Table 2: SLS 573 Measurement Rule

INFORMATION PROVIDED					MEASUREMENT RULES	DEFINITION RULES	COVERAGE RULES	SUPPLEMENTARY
CLASSIFICATION TABLE								
2. Soffit of slabs	1 Slab thickness less than ≤ 150 mm	1 Horizontal 2 sloping ≤ 15°	m2		M5. No deduction shall be made for openings of 0.5 m2 or less			

Source: SLS 573

However, according to the Revit quantity take off these minor voids are also deducted by the software.

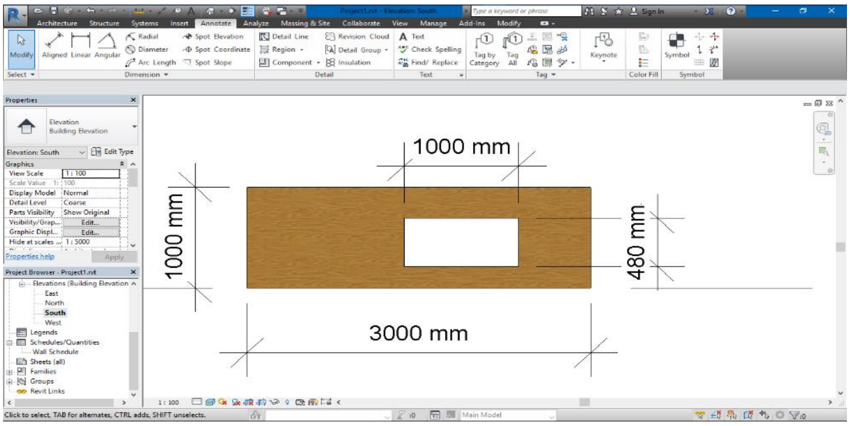

Figure 1: Revit model

The considering plywood sheet is shown in Figure 1, measuring the area of plywood sheet according to the SLS 573 measurement rules the area should be as follows,

Table 3: Quantity Takeoff According to the SLS 573

No.	Description	Unit	Numbers	Times	Length	Width	Height	Quantiy	Total
1	15mm thk 2400mm X 1200mm marine Pllywood sheet								
	Plywood sheet		1	1	3.00	1.00		3.00	
	Ddt								
	Void		1	1	1.00	0.48		(0.48)	
		m^2							**3.00**

Thiwanka :
According to the SLS 573 there is no deductions for voids less than 0.5m2. therefore no deduction made for 0.48m2 void to the Total

Table 3 shows the quantity take off according to the SLS 573. Considering the example taken in Figure 1 taking off the area of plywood sheet as above, but when take off the area from the automated quantity take off in Revit schedules as follows,

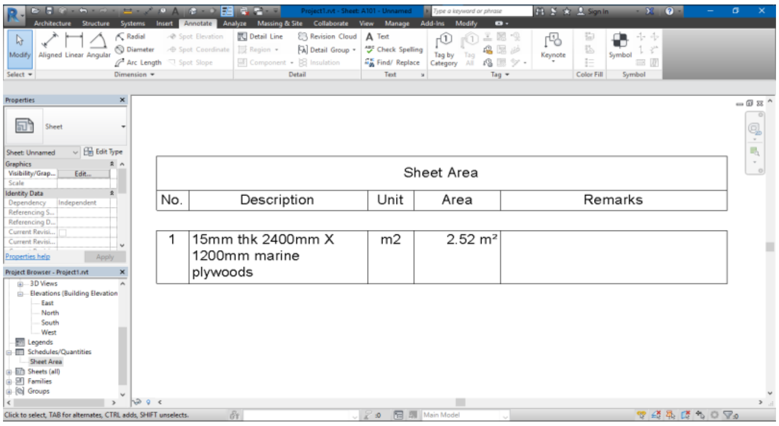

Figure 2: Automated QTO – Revit 2017

Figure 2 shows how the quantities take off in BIM models. According to the BIM, models automated quantity take off in Figure 2 it has deducted the 0.48 m^2 void areas of the plywood sheet.

4. DATA ANALYSIS

There were minor deviations in taking off quantities using Revit quantity schedules. As mentioned in the methodology chapter, the desk study was conducted to find out the deviations of BIM based BOQ from conventional BOQ. This research identified six deviations in the BIM based BOQ and these deviations forwarded to the semi structured expertise interview sessions to identify the acceptability of BIM based BOQ.

4.1. ELEMENT DEFINITION

At the desk study stage, this research could identify some element changes in the BIM based BOQ. These element changes were compared with the BIM based BOQ and conventional BOQ practice in Sri Lankan construction industry. SLS 573 document is used to prepare the BOQ. Definitions / Descriptions in BIM based BOQ can be prepared with the BIM standard and there is a deviation between these two standards.

4.2. SEMI STRUCTURED INTERVIEWS

Semi-structured interviews were used to identify the acceptability of BIM based BOQ for the Sri Lankan construction industry. As mentioned above six interview sessions were carried out among the experts in the construction industry. These experts were consultant quantity surveyors, pre-contract quantity surveyors and post contract quantity surveyors. Table 4 shows the summary of expert interviews. As explained in the above chapter the experts emphasized there are lots of benefits in using BIM based BOQ for the construction projects and there may be minor changes in practicing BIM based BOQ compare to the conventional BOQ in the common practice. Further to their explanations and opinions, they emphasized there are ways to overcome / minimize these adjustments and the changes.

According to the explanations of interviewees' pre-contract stage is the most suitable stage to overcome the minor deviations of BIM based BOQ. Further to the discussion of expert's interview, interviewees emphasised the SLS 573 should be amended to local practise to get the maximum benefits, features to the BIM based BOQ in Sri Lanka. Some interviewees emphasized that the deviation can be covered in preamble notes and avoid the conflict in BOQ quantities.

Table 4: Summary of Expert Interviews

No.	Interview	Deviation	Significance	Additions
1	SSI 001	We do not follow the measurement rule as it is in the SLS 573 therefore can be work according to the BIM based BOQ.	There is not a high significance.	Suggested to develop standards for Sri Lanka to use with BIM

No.	Interview	Deviation	Significance	Additions
2	SSI 002	Most of the cases the end result is same therefore the deviation is acceptable.	significant features can observe in vise versa during practice	
3	SSI 003	There is an impact to the measurement process but can be manageable.	Significance is depending on the project and the including's of the preamble notes.	Suggested to cover the deviation in preamble notes.
4	SSI 004	Quantity deviation is manageable.	Deviation is not highly significant	
5	SSI 005	There is an impact but the deviation can be covered by forming a new rate or provision.	Deviation is significant	Suggested to form a new rate or a provision to safe the contractor.
6	SSI 006	There is an impact to the project but can be manageable	Deviation is not highly significant	Emphasised the importance to amend the SLS 573.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

With above key findings now it can be concluded that BIM based BOQ are compatible for Sri Lanka construction industry, with some minor concerns which are manageable.

5.2. RECOMMENDATIONS

According to the key findings of this research, the researchers' recommendation is that the Sri Lankan quantity surveyors / cost estimators shall welcome the BIM technology to the Sri Lankan construction industry without worrying about its compatibility to local practice. Few further recommendations and suggestions can be made from expert interviews. It was emphasized that there is a requirement in amending the Sri Lankan standard of method of measurement (SLS 573) to easily practice with the BIM software. Some professionals in the industry use a non-standard method of measurement, which is easier to work with; but this method of measurement is not generally used for all the construction projects. Yet, it is worth reviewing it in light of BIM. According to the findings of expertise interviews that there are some quantity adjustments in BIM based BOQ and the end result of these adjustments are same as the conventional BOQ.

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CONSTRUCTION DELAYS IN SRI LANKA: PERSPECTIVE OF MAJOR PARTICIPANTS

B.N.M. Chathurangi*, Lalith De Silva and Mathusha Francis

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Delay can be defined as a slipping over the scheduled construction duration beyond the agreed completion date. Notwithstanding the all project participants suffer from inevitable consequences originated from construction delays, they all themselves influence to engender delays in more or less portions while contractors, consultants and employers conclusively afford massive deal. Therefore, this research tends to investigate the causes of delays from the perspective of responsible parties thereby suggest solutions to avoid them.

Initially the researchers conducted a comprehensive literature review to identify the causes of project delay. A total of 50 previously conducted researches were examined and 130 delay causes were found. Thereafter, 59 of the delay causes which frequently stand in Sri Lankan building construction context were filtered and responsible parties were recognised through opinions of 15 experts. Thence, the main questionnaire survey was carried out adapting 30 samples for each perspective of contractor, consultant and employer in order to identify the significance of delay causes by ranking them in each of the perspectives utilising Relative Importance Index (RII). The agreement between perspectives for the ranking was obtained from Spearman's Rank Correlation Coefficient (rs) and Kendall's Correlation of Concordance (W). Thereafter, the preventive measures to enrich responsibilities of major participants in order to avoid delays were explored through ten interviews.

Consequently, the study revealed that the contractor is the most responsible party for construction delays. Eventually, the strategic framework was developed to enrich responsibilities of the major participants on avoiding construction delays ameliorating elicited facts from the study thereof.

Keywords: *Construction Delays; Causes; Major Participants.*

1. INTRODUCTION

Construction industry is one of the significant sectors which emphasis a society achieves its goals towards development of economy. This consists complex and sophisticated process itself due to large number of participants involved (Divya & Ramya, 2015). A construction project consists of a unique set of high risk activities which should be accomplished by effective management in all stages in order to originate a unique output (Kesavan et al., 2015). Meanwhile, the successful endeavour on project depends on achieving goals and objectives within predetermined cost and time (Shaikh et al., 2010). A project cannot be considered as successful until it satisfies the prime measures defined for it (Mahamid et al, 2012). Delay is defined as the time overrun either beyond completion date specified in a contract or the date that parties agree upon for delivery of a project (Alwi & Hampson, 2003). Delays lead projects towards either extension or acceleration which both results in additional cost and further to disputes (Sambasivan et al. 2017). Disputes, arbitration, litigation and even total abandonment can be resulted due to delays in construction projects (Sambasivan & Soon 2007).

Since the multiparty involvement, construction delays entail aggregate negative consequences on project participants (Divya & Ramya 2015). Contractors who instigate any delay themselves confront financial

*Corresponding Author: E-mail – bnmchathurangi@gmail.com

penalties called liquidated damages (Thomas et al., 2004). Apart from that, delays induce dissatisfaction and loss of revenue to the employer (Jeyakanthan & Jayawardane 2012). Nevertheless, delays arise due to the issues related to project stakeholders such as clients, contractors, subcontractors and consultants (Abisuga et al., 2014).

However, the necessity of acceleration or extending duration encounters some cost augment derived from the delays (Aibinu & Jagboro, 2002). Whereas, preventing and mitigating delays have potential to save cost (Abdul-Rahman et al., 2006). In addition to that, identification of actual delay causes is essential in order to avoid and minimise delays (Divya & Ramya 2015). Therefore, the research investigates the causes of delays from the perspective of responsible parties and suggests solutions to avoid the project delays and finally develop a framework of avoiding delays in construction projects.

2. LITERATURE REVIEW

2.1. *NATURE OF CONSTRUCTION PROJECTS*

The construction industry represents a significant portion of the economy in spite of developed or developing (Monyane et al., 2016). Construction can be commentated as a specific project industry due to its inherent features such as uniqueness, circumscribed location and temporality in production (Karna et al. 2013). A production process of a construction project usually consists of three major phases called project conception which recognises the need and primary concept, project design which converts the concept into a manifestation and project construction which converts the design into reality (Chan & Kumaraswamy 1997). Usually, construction projects involve design and build of a new structure (Zwikael, 2009). Construction projects are classified in accordance with two parameters called constructed facility and type of client (Ankrah et al., 2008). A construction project is a process in which employer and other project participants are brought together to proceed with interdependent relationships towards achieving a project goals (Karna & Junnonen 2016). However, construction project team as a "Temporary Multi Organization (TMO)" which is formed by different entities and further the relationships between parties within the project team are naturally interdependent and uncertain and can be called as "independent autonomy". This is formally governed by a contract (Love et al. 2002). Thus, various construction project stakeholders either direct or indirect such as owners, project managers, designers, shareholders, legal authorities, labours, sub-contractors, suppliers, service providers, competitors, financial institutions, insurance companies, media organisations, neighbours and community representatives, the general public, government establishments, visitors, regional development agencies, the natural environment and pressure groups are involved (Jin et al. 2017). Stakeholder management has great relevance on the success of a project (Rathenam et al. 2016). Although the different participants involved in construction process may have divergent interest depending on their own objectives, there must be an agreement between them to achieve project objectives (Toor & Ogunlana, 2009). However, it is obvious that interests of project participants highly affect the project performance either positively or negatively (Samset, 2003).

2.2. *CONSTRUCTION PROJECT DELAYS*

Construction projects seldom run smoothly (Thomas et al., 2004). Performance of modern construction projects is disturbed by the complex and uncertain nature in physical, financial and economic environment due to the employment of advance technologies, changing owner requirements and multi-party involvement (Divya & Ramya 2015). Success of a construction project is measured in terms of time, cost and quality which accomplished within the predetermined limitations (Frimpong et al., 2003). However, Mahamid (2016) exposed that time, cost and quality constraints as "the golden triangle" in a project success. Time is concerned as a head most constraint for success of a project (Mahamid, 2016). The contract time, which can be defined as the maximum time allowed for the contractor to complete all work specified in the contract documents (Herbsman et al., 1995). A construction project delay is defined as "the non-completion of the project within the original or stipulated or agreed contract period" (Dolage & Rathnamali 2013). The two main categories of delays can be seen in construction projects called 'inexcusable delays' which are caused solely by either contractor or supplier subjected to delay damages or compensation to the employer that no relief is given to the contractor and 'excusable delays' which are caused by employer or any of his representatives and causes beyond the control of project team (Tumi et al., 2009).

2.3. *AVOIDING CONSTRUCTION DELAYS*

The frequent effects of delays are cost overrun, time overrun, litigation, lack of continuity by client and arbitration (Amoatey et al. 2015). According to Sambasivan and Soon (2007), the most significant effects of delays are time overrun, cost overrun, disputes, arbitration, litigation and total abandonment. The negative effects of construction project delays impact the employer, contractor and consultant by emerging conflicts between parties, mistrust, litigation and cash-flow problems (Divya & Ramya 2015). However, 78-90% of construction projects in Sri Lanka have experienced time overruns during 2010-2012 periods (Ramachandra et al., 2014). An effective project management team can proceed by utilising proactive strategic measures prior to effects of the delay become reality (Zailani et al. 2016). Similarly, growing importance of time is significant for the employer in terms of performance to obtaining revenue early from the investment and for the contractor in terms of obtaining profit from their business (Alaghbari et al., 2007). Overcoming or mitigating delays heavily depends on the delay causes, nature of the cause and resource availability (Abdul-Rahman et al. 2006).

It was identified that design changes, labour productivity issues, inadequate planning and resource shortages as major delay causes (Kaming et al. 1997). According to a case study regarding delay factors in building construction projects in Libya shows that slow decision making, low supervision, material shortages, project scope changes, non-finalised design documents, adverse weather conditions, material delivery delays, financial problems, owner interference, delays in claim settlements and material price fluctuations are critical delay factors (Shebob et al., 2011). Accordingly, manpower issues such as lack of skills, labour productivity and mismanagement of project manager, method related causes such as problems in planning and approval, design changes, poor control and obtaining permits, supply chain issues such as delivery of materials, financial issues such as delayed payments by the employer and cash flow problems as significant causes of delays in construction projects (Mitra & Tan 2012). However, delay events occur due to individual or joint contributions of project participants prominently contractor and the client (Aibinu & Jagboro 2002). A clear understanding of delay by the project team members, dominant with contractor help to avoid or minimize delays (Ayudhya 2011). In addition, identification of responsible party is required to mitigate construction delays (El-Razek, Bassioni & Mobarak 2008).

3. RESEARCH METHODOLOGY

Basically, a research approach of any research can be a one of three ways as qualitative or quantitative or mix of both. Integration or mixing of both qualitative and quantitative approaches is named as mixed approach (Creswell 2012). Accordingly, a three rounds of data collection was conducted in this study which consists of both the quantitative and qualitative approaches in order to attain the established aim. Initial study was implemented in order to identify research gap, research problem, aim, objectives, scope and limitations. The causes of delays were found out by systematically reviewing 50 previously done studies on construction delays. Preliminary questionnaire as first round of data collection was prepared based on that to sort out delay causes which can be seen in construction stage of the project in Sri Lankan context. Main questionnaire survey, second round data collection was carried out as a close-ended questionnaire with the use of filtered delay causes through preliminary survey in order to rank them in accordance with the significance of each for construction delays and to identify the most responsible party thereby. Correspondingly, perspectives of contractor, consultant and employer were considered and 30 sampling units for each perspective were selected through simple random sampling. Relative Importance Index (RII) was computed utilising below equation (Eq 01) to rank the significance of delay causes. Spearman's Rank Correlation Coefficient (SRCC) and Kendall's Coefficient of Concordance (KCC) were utilised to obtain the relationship between parties for the ranking.

$$Relative\ Importance\ Index\ (RII) = \frac{\sum w}{AxN} \qquad \text{Eq. (01)}$$

Where, W = Weighting given to each factor by each practitioner, A = Highest Weight, N = Total number of Authors

$$Spearman's Rank\ Correlation\ Coefficient\ (r_s) = 1 - \frac{6\sum d_i^2}{n(n^2-1)} \qquad \text{Eq. (02)}$$

$$Kendall's\ Coefficient\ of\ Concordance\ (W) = \frac{12S}{m^2\ (N)(N^2-1)} \quad \text{Eq. (03)}$$

Semi structured interview was deployed as third round data collection in order to get means of avoiding construction delays. Thus, the research involved Five (05) experienced professionals from both contractor and consultant organisations.

4. RESEARCHES FINDINGS

The systematic literature review was executed to identify the causes of delays. Thus, this formed a foundation for data collection. Accordingly, 50 numbers of previous researches conducted during last two decades (1997-2017) by various authors in the world regarding the identification of delay causes in construction projects. Numbers of deployed researches during 1st and 2nd decades were 15 and 35 respectively. Thence, 130 of delay causes were identified. After conducting a preliminary survey, 59 numbers of delay causes which exceeds the 80% acceptance percentage were extracted as most frequent delay causes in Sri Lankan building construction industry. These are taken to the main questionnaire survey. Thus, the significance of each delay cause for construction delays was obtained in three perspectives as, contractor's perspective, consultant's perspective and employer's perspective. Although 59 of factors were filtered in the preliminary survey, 70 of factors had to be employed in main questionnaire survey since some of the factors were influenced by all the three parties or sometimes two parties and therefore to be defined as separate causes in order to obtain most responsible party for delays. Ranking of delay causes can be seen as follows;

Table 1: Causes of Construction Delays

No	Delay causes	Responsible Party	Contractor's Perspective		Consultant's Perspective		Employer's Perspective	
			RII	Rank	RII	Rank	RII	Rank
1	Contractor's improper planning, scheduling and controlling	Contractor	0.9840	1	0.9200	1	0.8240	1
2	Contractor's slow decision making	Contractor	0.9520	2	0.8960	2	0.7760	3
3	Poor communication and coordination of contractor	Contractor	0.8880	3	0.7760	15	0.7680	4
4	Poor site management and supervision	Contractor	0.8880	3	0.8080	8	0.7920	2
5	Consultant's slow decision making	Consultant	0.8720	5	0.7680	17	0.7120	13
6	Difficult in financing project by contractor	Contractor	0.8720	5	0.8080	8	0.7440	5
7	Late procurement in material	Contractor	0.8720	5	0.8160	6	0.7360	8
8	Poor communication and coordination of consultant	Consultant	0.8640	8	0.7760	15	0.6320	30
9	Employer's slow decision making	Employer	0.8640	8	0.7600	19	0.6400	28
10	Payment delay for completed works	Employer	0.8640	8	0.7440	24	0.7120	13
11	Skill labour shortages at site	Contractor	0.8640	8	0.7840	13	0.7440	5
12	Changing orders during construction	Employer	0.8560	12	0.7920	11	0.6720	19
13	Inadequate contractor's experience	Contractor	0.8560	12	0.7920	11	0.7360	8
14	Mistakes during construction by the contractor	Contractor	0.8480	14	0.7120	32	0.5840	45
15	Poor communication and coordination of Employer	Employer	0.8400	15	0.7440	24	0.5440	53
16	Improper construction methods used by the contractor	Contractor	0.8400	15	0.6720	40	0.5840	45
17	Inadequate managerial skills of contractor	Contractor	0.8320	17	0.8560	3	0.7440	5
18	Mistakes and discrepancies in design documents	Consultant	0.8240	18	0.6640	41	0.5920	40
19	Material delivery delays	Contractor	0.8240	18	0.7520	20	0.6480	24
20	Consultant's slow response for inquiries	Consultant	0.8240	18	0.7520	20	0.6240	32
21	Delay in approving and reviewing by consultant	Consultant	0.8160	21	0.7440	24	0.6160	35
22	Low quality material usage	Contractor	0.8160	21	0.6000	58	0.5680	50
23	Poor workmanship	Contractor	0.8160	21	0.7200	30	0.6240	32
24	Insufficient staff of contractor	Contractor	0.8160	21	0.8080	8	0.7280	11

25	Insufficient working drawing details	Consultant	0.8080	25	0.6240	52	0.5760	47
26	Poor qualifications of contractor’s technical staff	Contractor	0.8080	25	0.7520	20	0.7120	13
27	Contractor's poor project management	Contractor	0.8080	25	0.8240	4	0.7360	8
28	Consultant's poor project management	Consultant	0.8080	25	0.6480	43	0.6480	24
29	Reworks in construction	Contractor	0.8000	29	0.7120	32	0.6800	17
30	Inadequate consultant's experience	Consultant	0.8000	29	0.6080	56	0.5920	40
31	Poor contract management	Consultant	0.7920	31	0.7520	20	0.7040	16
32	Material shortages at site	Contractor	0.7840	32	0.7680	17	0.6640	21
33	Handling complexity of the project by the contractor	Contractor	0.7840	32	0.6080	56	0.6080	38
34	Delay in approvals by the employer	Employer	0.7840	32	0.7840	13	0.6560	23
35	Employer's financial problems	Employer	0.7680	35	0.8160	6	0.6640	21
36	Lack of adequate monitoring and instructions by consultant	Consultant	0.7680	35	0.5760	60	0.5040	62
37	Damages to stored material while they are needed urgently	Contractor	0.7680	35	0.7120	32	0.5920	40
38	Less cooperativeness of the employer	Employer	0.7680	35	0.6480	43	0.5440	53
39	Incomplete contract documentations (Main contract)	Consultant	0.7680	35	0.7280	29	0.6800	17
40	Late handover site by employer	Employer	0.7680	35	0.7360	27	0.6160	35
41	Poor labour productivity	Contractor	0.7600	41	0.8240	4	0.7280	11
42	Conflicts of the contractor with other parties	Contractor	0.7520	42	0.7360	27	0.6480	24
43	Handling complexity of the project by the consultant	Consultant	0.7440	43	0.5600	62	0.5520	52
44	Equipment failure and maintenance	Contractor	0.7440	43	0.6480	43	0.5360	58
45	Low efficiency of equipment	Contractor	0.7440	43	0.6880	36	0.5920	40
46	Preparation of shop drawings/schedules and material samples	Contractor	0.7360	46	0.6560	42	0.5760	47
47	Delay in commencement of the construction	Contractor	0.7360	46	0.6480	43	0.5920	40
48	Sub-contractor related issues	Contractor	0.7280	48	0.7040	35	0.6720	19
49	Long inspection procedure of completed works	Consultant	0.7280	48	0.6480	43	0.5760	47
50	Conflicts of the employer with other parties	Employer	0.7280	48	0.6480	43	0.6080	38
51	Organisational structure linking to the project	Contractor	0.7200	51	0.6000	58	0.5680	50
52	Conflicts of the consultant with other parties	Consultant	0.7200	51	0.6480	43	0.6320	30
53	Equipment shortages at site	Contractor	0.7120	53	0.7200	30	0.6480	24
54	Undefined scope of works	Consultant	0.7120	53	0.6880	36	0.6400	28
55	Equipment delivery delays	Contractor	0.6960	55	0.6880	36	0.6160	35
56	Owner interference	Employer	0.6880	56	0.6160	54	0.5440	53
57	Shortages of unskilled labours	Contractor	0.6800	57	0.6800	36	0.6240	32
58	Working environment at site	Contractor	0.6720	58	0.4960	67	0.4480	65
59	Slow evaluation of completed works	Consultant	0.6560	59	0.5600	62	0.4720	64
60	Claims and disputes initiated by the contractor	Contractor	0.6560	59	0.5680	61	0.5360	58
61	Claims and disputes initiated by the consultants	Consultant	0.6560	59	0.4960	67	0.4080	68
62	Claims and disputes initiated by the Employer	Employer	0.6560	59	0.5120	64	0.3920	69
63	Service availability to the site	Contractor	0.6560	59	0.6160	54	0.5040	62
64	Labour disputes at site	Contractor	0.6560	59	0.6240	52	0.5440	53
65	Improper equipment	Contractor	0.6400	65	0.6480	43	0.5440	53
66	Handling complexity of the project by the Employer	Employer	0.6400	65	0.4960	67	0.4240	67
67	Ineffective delay penalties	Consultant	0.6400	65	0.4720	70	0.3600	70
68	Poor site arrangement	Contractor	0.6400	65	0.5120	64	0.5120	61
69	On site accidents	Contractor	0.6160	69	0.5120	64	0.4400	66
70	Inadequate staff of consultant	Consultant	0.6000	70	0.6400	51	0.5280	60

Since the ranking was obtained in three different perspectives, the strength of association between rankings was computed utilising SRCC (r^s). The results of SRCC vary between -1 to +1 where -1 implies strong negative relationship, 0 indicate neutral and +1 implies strong positive relationship. According to table, r^s between the contractor's perspective and consultant are 0.747 which implies a positive correlation of agreement between the contractor and the consultant. Similarly, coefficient value of 0.724 between contractor and employer also represents the positive agreement between the ranks. Meanwhile, the coefficient value between consultant and employer is 0.903 which implies higher convenience to the strong positive relationship between rankings. Similar to the SRCC, the values KCC also varies in the range of -1 to +1 when -1 implies perfectly negative relationship (disagreement) while +1 implies perfectly positive relationship (agreement) and 0 indicates very little or no correlation. However, the computed value for W to obtain relationship among contractor, consultant and employer's perspectives was 0.85 which intimate positive relationship regarding the rankings. Then the responsibility of each party for the construction delay was calculated. According to the contractor's perspective, the contractor is the most responsible party by acquiring 78% while consultant's and employer's responsibilities are 76% and 77% respectively. According to the consultant's perspective also the contractor is the most responsible party for construction delay while having 71% and the consultant's and employer's responsibilities are 65% and 69% respectively. According to the employer's perspective also contractor is the most responsible party by acquiring 71% and the consultant's and employer's responsibilities are 65% and 69% respectively. In all events, the results of the questionnaire survey in all the three perspectives of contractor, consultant and employer clearly exhibited that the most responsible party for the construction delay is contractor.

Semi structured interviews were conducted in order to find out preventive measures for avoiding construction delays concerning delay causes related to major responsible party. In compliance with that, 39 contractor related delay causes were divided into 11 categories considering the nature of the delay cause as management related, equipment related, labour related, material related, technology related, financial related, construction related, site-operation related, stakeholder management related, subcontractor related and contractor's technical staff related. Consequently, all the findings in qualitative approach were gathered in a framework development.

5. CONCLUSIONS

A construction delay is known as slipping over pre-determined time duration for project fulfilment beyond the established completion date. Although numerous researches were conducted previously with regard to identification of the construction delays, recognising effects of the construction delays and investigation of mitigating measures, the construction delays still stand in the construction industry which adversely effect on project participants. The project participants, especially major participants like contractor, consultant and employer suffer from financial losses, conflicts and disputes, resource wastages, litigation, dissatisfaction and perhaps total abandonment of the projects, the liability of originating delay causes also rests on them. The utilisation of preventive measures henceforth to suppressed construction delays will provide noble satisfaction to project participants. Since the construction projects involves various participants and all of them contributes in different portions to the construction delays, identification of major responsible party and avoid accompanied delay causes significantly accommodate reducing large segment of construction delays. However, causes of delays extracted from 130 causes of delays which identified through a systematic literature review of previously conducted researches were employed in conducted preliminary data collection process to filtering delay causes stand in Sri Lankan building construction industry that can be controlled by project participants. Among the extracted delay causes from literature review fifty-nine (59) delay causes which were filtered concerning as more frequent in the industry which had obtained more than 80% accepted percentage. The agreement for the ranking of delay causes once in between two perspectives was obtained through SRCC (r^s). The resulted r^s values represented the positive relationship of agreement between contractor- consultant perspectives, contractor- employer perspectives and consultant-employer perspectives respectively since the results were imminent to +1. Meanwhile, the agreement among three different perspectives for ranking of delay causes were computed by KCC (W) and result of this correlation also portrayed positive relationship. The eventual results of the quantitative analysis show that massive responsibility rests on the contractor to avoid construction methods. The following framework indicate the causes and the measures to avoid construction delays in Sri Lanka.

Table 2: Framework of Avoiding Construction Delays in Sri Lanka: Perspective of Major Participants

	Management Related Delay Causes	**Equipment Related Delay Causes**	**Material Related Delay Causes**	**Technology Related Delay Causes**	**Financial Related Delay Causes**
	Contractor's improper planning, scheduling and controlling Poor site management and supervision Inadequate managerial skills Slow decision making	Shortages of equipment improper equipment equipment delivery delays equipment failure and maintenance low efficiency of equipment	Material delivery delays Material shortages Low quality material usage Damage of stored material while they are needed urgently	Improper construction methods used by the contractor Complexity of the project Inadequate contractor's experience	Difficulties in financing project
	Preventive Measures				
Contractor	Proactive planning Feedback system Development of management competencies Development of efficient control ability Establishing management hierarchy Employing experienced supervisory staff Familiarization of supervisors to site operations Accurate project record keeping Proper observation of the work flow and events Usage of construction time estimation models Risk identification, assessment and response Frequent progress meetings Following PMBOK by project managers	Alternative resource sharing mechanisms Awareness of the resource strength and obtain up-to date machinery Prepare and update the equipment allocation schedule Purchase new equipment which required Additional equipment to be kept when use to equipment breakdown Concerning the repair and maintenance schedule	Effective management of a material procurement schedule Hiring of an independent engineer to supervise and monitor the progress of construction works in relation to material Proper planned area for material shortages Aware about material inventory management Establishing feedback system to notify the required materials, time for purchasing materials	Realized the benefits of using contemporary methods and techniques, in addition to appropriate exploitation of modern equipment in construction projects Significant concern on contractor's technical competency Employ specialist subcontractors who have experienced in particular work Obtaining approvals for the method statements Perform work studies Continuous workshops for training staff regarding new technologies Collaborative approach with other parties	Adequate contingency allocation Contractor should ensure the advance payment is used to finance the project activities Identification and assessment of risk and responses Plan the income and expenditure properly Identify the required monetary resources for projects by accurate tendering Obtain bank loans Alternative financial plans Keeping sufficient contingency amount
Consultant	Following PMBOK by consultant's project managers Clear definition to project scope Issuing on time notices and instructions in compliance with the Conditions of Contract	Specify the equipment particularly required for project Carefully concerning the pre-qualification documents submitted by the contractor	Preparing accurate specifications Descriptive specifications	Highly concern the contractor's experience in pre-qualification evaluation Ask to submit method statements before work started Clearly define the project scope	Significant concern on contractor's prequalification Evaluate payment applications accurately and on time Concern the financial stability of the contractor in selection
Client	Giving freedom to contractor to add management related suggestions Facilitate the contractor's decision making by providing on time information as requested by the contractor	Clearly mention his requirements from the project let consultant to select the contractor by considering the requirement of the project rather than go for lowest bid	Proper indication of material quality Approval for material selections on time Supply the right material at the right time which agreed to supply	Introduce the nominated subcontractors who specialist in particular work Consider the contractors past experience in pre-qualification Clearly convince his requirements to the project team	On time payment Make the early financial arrangement

	Construction Related Delay Causes	Site operation Related Delay Causes	Stakeholder management Related Delay Causes	Subcontractor Related Delay Causes	Technical Staff Related Delay Causes
	Mistakes during construction Delay in commencement Poor Workmanship Preparation of shop drawing and schedule	On site accidents Working environment at site Service availability to the site Poor site arrangement	Organizational structure linking to the project Poor communication and coordination Claims and disputes Conflicts	Subcontractor delays Poor performance and Conflicts Subcontractor payments	Poor qualifications of the technical staff Insufficient staff
	Preventive Measures				
Contractor	Awareness of supervisors regarding the client requirements Troubleshooting Proper planning the sequence of work prior commencement Evaluate the previous experiences to avoid mistakes Onsite training programs In line with the drawings Comply with the conditions of contract Proper Supervision	Coordination and corporation in locating and relocating service lines Well perform environmental and social assessment Collecting the mapping of underground utility data Well prepare the project site Adequate safety regulations Regular safety meetings Visit the site before bidding the project Perform social and environmental assessment to avoid future conflicts	Identification of the objective of each stakeholder Comply with conditions of contract Transparency of the information Use written agreements Just-in problem solving methods Appropriate communication protocol Multimedia information management Record maintenance Respecting each other Effective problem solving methods Communication protocols Clear information Joint and collaborative work Developing team spirit Create project culture Participatory approach	Make contractual agreements Regular Meetings Clearly defined the scope Evaluated the progress Concerning the subcontractor's past experience on particular works which they are intended to employ On time payments Daily superintendence Long term strategic relationships Coordination &cooperation Not to withhold larger amount of retention Set plans together with subcontractor Selection through prequalification Adhere to quality standards	Task proficiency Conducting continuous training programs Quality and efficiency may be enhanced through job training Check the performance level of the staff Minimum qualification level to be added as a requirement Attractive salary and incentives Keep proper human resource management team in order to notify the required professionals and technical personal Identification of capabilities of each personnel to assign "Right man to right job"
Consultant	Close inspection of the consultant Regular site inspections Issue non-conforming certificates for incomplete works Prepare descriptive specifications	Properly include preliminary to the BOQ	Comply with conditions of contract Identification of the objective of each stakeholder Comply with conditions of contract Transparency of the information Establishing respecting culture		Prequalification procedure Well observing the prequalification Mentioning the requirement of technical staff in the tender document
Client	Select the right contractor lies with the client in most projects	Obtaining necessary approvals regarding the construction by government and other organization Enforce acceptance standards and consider designated site proposals as criteria for tender evaluation	Respecting each other Effective problem solving methods Communication protocols Clear information Joint and collaborative work	Introduce competent subcontractors Concern the past relationship of the subcontractors with the main contractor when introducing a nominated subcontractor	

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CUSTOMER RELATIONSHIP MANAGEMENT IN FACILITIES MANAGEMENT: A STUDY OF OFFICE BUILDINGS IN SRI LANKA

H.M.P.K. Herath, Damitha Rajini*, Uthpala Rathnayake and Nimesha Jayasena

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Customer Relationship Management (CRM) is a strategy used by the business organisations in order to optimise the service efficiency in the current competitive business environment. The aim of CRM in Facilities Management (FM) is to build an acceptable long-term relationship with customers and users of the facility for long term sustainability. Though CRM in FM is an area gaining importance, the CRM practices in FM is still unclear. Therefore, this study intends to develop an understanding of the current CRM practices in FM in Sri Lankan Office buildings focusing on the tenants, identify the issues and propose strategies to overcome them. The case study approach was adopted as the research method and the required data were collected from both the management and tenants of the selected cases. The data collection was done through semi structured interviews whereas the analysis was conducted through code-based content analysis. The results of the study showed that CRM in FM in Sri Lankan office buildings sector is at a low level and there are different issues related with CRM process, employees who involved in providing customer services and the technology used for CRM. The identified common issues were unavailability of a mechanism to evaluate CRM process or tenants to give their feedback, the FM employees' poor communication skills, ineffectiveness of manual processes used for some CRM activities and the like. Conducting customer satisfaction surveys, training and development on CRM practices, periodical tenant meeting, etc. are the proposed strategies to overcome those issues. It was also established that the current CRM practices can be enhanced by implementing the identified strategies, with the effort of all the parties involved in service provision for tenants in Sri Lankan office buildings. The results of the study guide the industry professionals to improve the CRM practices related to FM in Sri Lankan office buildings.

Keywords: *Customer Relationship Management (CRM); Facilities Management (FM); Office Buildings; Tenants.*

1. INTRODUCTION

Customer Relationship Management (CRM) is a practice and a strategy that organisations use to retain, acquire, identify and cherish profitable customers by constructing and sustaining long-term relationships with them (Adikaram, 2016). As mentioned by B.C. Opara and Opara (2016), it involves the integration of people, process and technology to enhance customer satisfaction with the view of achieving organisational objectives. CRM in Facilities Management (FM) can be defined as the interaction of FM department with core business or users of the premises at all levels of FM to build a long-term acceptable relationship (Naaranoja, 2011). Good CRM practices should therefore be maintained among the FM department and its customers to deliver a quality FM service and to achieve the core business objectives (Ogbeifun et al., 2016). Though, a number of previous researchers (Hoots, 2005; Naaranoja, 2011; Ogbeifun et al., 2016) have highlighted the the importance of customer-oriented approach for FM, still the literature and empirical findings in this area is limited, especially in the Sri Lankan context. Therefore, a research need was identified to investigate issues in current CRM practices related to FM and to find strategies to overcome those issues in the Sri Lankan context. Thus, this paper presents the findings of a study carried out, with the aim of investigating the current CRM practices related to FM in Sri Lankan office buildings together with identifying the existing issues and proposing strategies to improve the current CRM practices. The paper starts with a literature review on the

*Corresponding Author: E-mail – damithar@uom.lk

concept of CRM and its applications for FM. Then it presents the research methodology followed by data analysis and research findings. Finally, the conclusions of the study are presented.

2. LITERATURE REVIEW

2.1. OVERVIEW OF CUSTOMER RELATIONSHIP MANAGEMENT

Customers are the most valuable resource in a business (Asadi et al., 2013). Without customers, there will be no market place for services, no innovations and no returns or profit and, at least no survival (Amarathunga et al., 2004). Successful businesses are running today by questioning about their customer needs and paying attention to them. It is supported by CRM, which helps organisations to increase the revenue and obtain higher profits by properly treating their customers (Asadi et al., 2013). According to B.C. Opara and Opara (2016), CRM is a business strategy consisting with a broad range of organisational and operational activities that provides an overall combination of all areas of business including marketing, finance, production and personnel. It is also an organisational strategic tool to face competitiveness, which focuses to obtain new customers and maintain existing customers to increase competitive advantages in the business world (Tekin, 2013). As mentioned by Ragins and Greco (2003), CRM has emerged to represent more balanced performance on continuing relationships rather than simply having individual dealings. Hence, CRM in any organisation is characterized as an important and vital principle (Ghalenooie & Sarvestani, 2016).

Applying best CRM practices will result in several benefits to an organisation (Ragins & Greco, 2003). These include enhanced loyalty of customers (Asadi et al., 2013), improved communication, increased customer retention rates, reduced spending rates on CRM, reduced legal condition related costs and enhanced customer knowledge and feedback (Hughes, 2011; Buttle, 2004; Chen & Popovich, 2003; Eggert et al., 2006). Hence, effective CRM will lead to increase an organisation's income and ultimately gain higher profits.

According to Mendoza et al. (2007), human, process and technology are the three fundamental resources which integrated with CRM strategy. A number of previous researchers namely, Chen and Popovich (2003); Couldwell (1998); Rigo et al. (2016) identified those three factors as determinants of effective CRM, which have been described in detail below.

- **Process**- Maintaining best process for identifying the customer requirements is one of the main CRM strategies since retaining a customer is more profitable than building a relationship with a new customer. There are some organisational practices to identify the customers' perspectives like measuring customer satisfaction, performance assessment and handling customer complaints (Chen & Popovich, 2003).
- **Human/ people factors** - Effectiveness of the CRM largely depends on the people who are performing it, even the process and technology helps for CRM (Rigo *et al.,* 2016). Top management commitment is an essential factor for strategic development in CRM and according to Brito (2011), employees should be provided with necessary trainings and motivation to meet customer expectations and needs. Effective communication can identify the customer's needs and manage the problems which are arisen due to poor services provided by the organisation. Therefore, a competent and skilled person should be appointed to handle relationships with the customers. In this sense, human factors and behaviours are more important in maintaining strong CRM (Chen & Popovich, 2003).
- **Technology**- Technology applications for CRM include front office and back office functions with the organisation's customer touch points (Fickel, 1999). Electronic CRM equips electronic or traditional channels (Milovic, 2011). Through the technology platform like the internet, an effective customer relationship can be developed. It would be helpful for customer retention and to improve the satisfaction and loyalty of customers (Behravan & Rahman, 2012).

Osarenkhoe and Bennani (2007); Parvatiyar and Sheth (2001) as well as Oztaysi et al. (2011) identified various CRM strategies coming under process, human and technology related factors. Accordingly, maintaining a dialog with customers by arranging regular meetings, measuring customer satisfaction, setting realistic targets and assessing performance of service provision, improving service quality, investing to improve the skills and competencies of workers involved in CRM, and using relationship-based interfaces and technology are the commonly used CRM strategies in the global context.

2.2. CUSTOMER RELATIONSHIP MANAGEMENT IN FACILITIES MANAGEMENT

The following sections describe the importance of CRM for FM, CRM practices in FM and the associated issues with those practices.

2.2.1. INTRODUCTION TO CUSTOMER RELATIONSHIP MANAGEMENT IN FM AND ITS IMPORTANCE

According to International Facility Management Association (IFMA, 2009), FM is a profession, consists with multiple disciplines, which coordinates built environment by ensuring its functionality by integrating people, places, processes and technology of an organisation. It involves various activities to manage built assets and deliver services effectively (Amarathunga, 2000). FM fulfils the requirements of a facility and maintains the coordination between FM department and FM consumers. Therefore, it needs to be adjusted and balanced to meet the requirements of both parties.

For FM, its main customer is the executive management of the organisation, the complementary unit responsible for the implementation of the core functions of the organisation and service providers (Ogbeifun et al., 2016). Other customers can be identified as employees, employees of third parties, visitors including the organisation's customers and potential customers, stakeholders of the business and members of the public (FMworld, 2010). In the FM sector, CRM can be identified as a tool, which looks at the FM function as a customer intensive business function rather than facilities services cost centre. CRM in FM can therefore be understood in such a way that facility manager expects to build a long-term satisfactory relationship with customers and users of the building (Naaranoja, 2011).

Relationship management creates a good relationship between FM suppliers and customers (Coenen et al., 2013). As Tucker and Pitt (2010) pointed out, customer satisfaction is the second most important priority after loss of business due to facilities failure, and accordingly, managing critical FM services and appropriate relationships can be seen as important simultaneous things. Thus, the emphasis on the effective workplace has shifted from profit maximisation to customer satisfaction, emphasising strategic FM. All aspects of functions are designed and run to satisfy the FM customers by addressing their requirements for services. Therefore, managing customer relationships has become a facility manager's job (Hoots, 2005).

2.2.2. CUSTOMER RELATIONSHIP MANAGEMENT STRATEGIES USED IN FACILITIES MANAGEMENT

As Coenen et al. (2013) identified, relationship management is a key point to interact with each other as customers and FM professionals. When maintaining relationships with customers, FM department should first analyse its operations and facilities along with its capabilities. Therefore, it needs to be determined what could be delivered to the customer. Based on that, the policies, procedures and systems should be developed, and plans, programmes and budgets should be prepared (Barrett, 2000).

There are some activities, which help in maintaining the relationship between FM professionals and their customers and the assessment of their performance (Lavy, 2008). Those activities include effective communication in the form of periodic reports, comprehensive analysis about the assets and the development of objective planning with suitable budgetary allocations. According to Campbell and Finch (2004), the customer satisfaction is not limited to technical performance but also includes effective communication and management of expectations as well (Campbell & Finch, 2004). Therefore, as Hoots (2005) suggested, regular customer surveys or performance assessments should be conducted by the FM unit in order to improve the image of an organisation before its customers. The questions content should be varied from time to time with their objective of taking the customers concerns over a wide range of service providers by the FM units. Currently, internet has become one of the main communication strategies, and more benefits can be gained by using Information Technology (IT) for maintaining relationship with the customers (Barret, 1995). According to Naaranoja (2011), FM organisations can use IT to help CRM in FM like document management systems for drawings, letters, memos, and contract files, bookkeeping system linked to customer and space register, email messaging, extranet for maintenance manual information, etc.

2.2.3. ISSUES IN CUSTOMER RELATIONSHIP MANAGEMENT IN FACILITIES MANAGEMENT

There are numbers of issues due to poor CRM in FM such as, increasing the number of complaints, abate customer loyalty and less customer coming back to the organisation (Hoots, 2005). As Tax *et al.* (2013) highlighted, customer complaint is the key issue of poor CRM and it will affect the goodwill of the organisation. Ree and McLennan (2006) identified that without accurate CRM in FM, both external service value and internal service quality might be decreased as supply chain becomes weak. Further, poor employee loyalty to FM performance will ultimately lead to decrease the market share, profitability and growth of the organisation. Even the operatives of FM units put in their best to see that the facilities and services that support the core activities of their customers are up and running, they consider and pay attention to documentation, reporting and effective and efficient communication. Increasing of complaints can be seen when any part of the services is not functioning (Ogbeifun *et al.,* 2016). Hoots (2005) summarised that there are three main causes for customer dissatisfaction with FM services i.e. resources, response and respect. Lack of sufficient resources to meet customer needs, not having the ability to respond effectively to organisational requirements and absence of mutual respect between FM division and customers are examples for such dissatisfactions. Therefore, these factors affect towards the initiation of customer's issues like customer complaints and effective management of them is the basis for effective CRM in FM.

3. METHODOLOGY

The aim of this research was to investigate the issues in current CRM practices related to FM in office buildings in Sri Lanka and to find strategies to overcome those issues. The customers considered in this study were the tenants who are the main FM customers of office buildings. The case study method was used to carry out in-depth study for this research in order to achieve research objectives. Considering the availability of time and other inconvenience, the number of cases were limited to three and three (03) buildings. The buildings, where the spaces have been rented out to more than twenty tenants were selected as the cases. The three selected cases in this study were named as Cases A, Case B and Case C. Case A has rented out 30 numbers of office areas for tenants whereas Cases B and C have rented out 48 and 20 numbers of office areas respectively. The data collection was done from both the management as well as from the tenants of the selected buildings. Hence, in each case, one semi-structured interview was conducted with one management professional and the codes used in this paper to represent them in Cases A, B and C are M1, M2 and M3 respectively. Five tenants from each case were also interviewed for data collection and the codes used for tenants in the Cases A, B and C are TA-n, TB-n and TC-n respectively. All selected respondents had more than 5 years' work experiences within the selected cases. As the data analysis method, content analysis was used with the aid of NVivo software. The following sections discuss and analyse the findings of this study.

4. DISCUSSION

4.1. CURRENT PRACTICES OF CRM IN FM IN OFFICE BUILDINGS SRI LANKA

The data on current CRM practices in FM were collected from the representatives of FM department in each case. Accordingly, in Cases A and C, the facilities managers and in Case B, premises engineer were interviewed to collect the required data. All the respondents who represented the management mentioned that carrying out effective CRM practice provides benefits to any organisation. According to them, CRM is a strategy implemented to manage their interactions with the customers. Further, CRM helps to attract and win new customers as well as nurture and retain the customers that the organisation already has. According to M1 and M2, generating long-term satisfied customers and retaining them is the main benefit that they have gained by maintaining proper CRM in their organisations. Working with happy customers is easy compared to dissatisfied customers and if any issue occurs, it is easily negotiable. In addition, CRM accommodates effective communication among parties so that there will be minimum opportunities for misunderstandings and future issues. Respondent M3 stated that if an organisation has a CRM process, the customers will get the sense of feeling that they are cared, and the customers' trust will be enhanced and thus, it will help to create a good image about the FM department.

Generally CRM process includes activities such as; developing strategies, collection and use of customers' data, performance evaluation of the strategies and documented processes, etc. (Ngambi & Ndifor, 2015). However, in selected cases, there are no formal procedures or processes specifically implemented for CRM. As mentioned by M1, even though they do not have a special process which has been documented in a policy or anywhere for maintaining CRM, they always try to maintain a good relationship with their tenants by working with them face-to-face in a friendly manner and being available for them to approach at any time.

Respondent M2 pointed out that when tenants come to visit their building for the first time, premises engineer shows their renting spaces to them. After that, once the two parties agreed on terms and conditions of the service, the contract is signed. As the FM service providing party, the management of an office complex is responsible for providing several services, which are required to carry out tenants' office activities without any disturbance. The FM services provided by the selected cases include building and building services maintenance (electricity and water supply, air conditioning, security systems, lifts and escalators, etc.), janitorial services, security, occupational health and safety, mail service, etc. In Cases A and C, the janitorial services have been outsourced whereas security services of all the cases have been outsourced. In situations where both in-house and outsourced service provision can be seen, both parties should be involved to maintain a good CRM. As M2 mentioned, if there is any issue about the FM services, the tenants can communicate them to the FM department and get them solved. Further, if there is any need with respect to the operations of the rented space, tenants can get them fulfilled by contacting the relevant party. In case B, these issues are also handled by the premises engineer. The similar procedure can also be seen in Cases A and C as well where the facilities manager is communicated by the tenants and facilities manager has the ultimate responsibility with respect to the tenant services. However, as the responsible party to provide FM services to the tenants, the responsibility to make the tenants happy lies with the entire FM department.

The FM department generally comprises of managers, technicians and some other clerical staff to take care of administration works. All these parties directly contact with the tenants of the building and they also have a role to be paly when it comes to effective customer relations. Representative from top management like premises engineer in Cases B generally communicate with the top management of the tenant organisations. Technicians are assigned to perform building services related tasks and they are the people who directly work at the tenant's place and directly interact with the tenants. Therefore, as M1 described, they educate technicians during the induction i.e. how they should maintain a good relationship with tenants. The interviewees elaborated that the technicians are required to be concerned on their uniform, the language they use, how polite they talk to the tenants, patience in front of the tenant, responsiveness, etc. and especially how to handle difficult customers. In Cases A and B, a separate person has been assigned to handle customer calls and complaints with a dedicated telephone number. Therefore, they are also educated on the way that they should communicate with tenants. As highlighted by M1, all the managers and employees should have good communication skills in order to maintain a good relationship with tenants. Similarly, it was mentioned that they should have, decision-making skills and interpersonal skills as well. As, M2 of Case B pointed out, there should be a proper training and development procedures for the employees to maintain good CRM practices in the organisation. Except Case B which provides trainings for its technicians to improve their English knowledge, none of the other cases have paid attention to arrange such training programmes for their lower level employees. However, the HR departments of selected cases arrange performance interviews with their employees to evaluate the effectiveness of their works in regular intervals.

Retaining existing tenants is the most important concern in office complexes. The biggest determinant of tenant satisfaction and relationships is service quality and therefore, as the respondents from all the cases mentioned, they take immediate actions for tenant's complaints to provide them with a speedy service. Further, they always take necessary actions to improve the service quality. Evaluating the effectiveness of the CRM practices also provide necessary information about the tenants and their requirement to maintain a good relationship. Thus, to further enhance the service quality and effective relationships, Case B conducts a monthly meeting with its tenants. Here, the representatives from tenant organisations and the representatives of FM division get together and discuss the matters and come up with solutions. The representatives of the organisations which provide outsourced FM services are also required to attend these meetings. Moreover, in Case B, refresher meetings are also conducted with the FM employees weekly to ensure that all the expectations of their tenants are met. In the briefing, they discuss about service delays and reasons for them. Further, they decide on actions that can be taken to eliminate the issues and guide their workers to achieve them. However, as M1 and M3 disclosed, even though they do not have any practices to evaluate the effectiveness of the CRM, normally they arrange meetings with their tenants in case of emergency or at request of the tenants. Getting feedbacks from tenants will provide a clear understanding on tenants' expectations from the service provider. Case A uses a special mechanism for getting feedback from their tenants via emails. Normally it happens after they provided services like maintenance. In Case B, the feedback is taken during monthly tenants meetings.

As the study revealed, telephone calls and emails are the most widely used communication techniques in selected cases whereas formal letters are used in case of a special situation like requesting permission to get some help to renovate premises or repair the building, request some financial concerns related to the rent of the building, etc. In addition to that, the general tools and techniques used to maintain effective relationship with tenants in office complexes include memos, relationship-based interfaces as well as work order procedures to get maintenance jobs done. In Cases A, B and C, e-mails and relationship-based interfaces are the only technology based applications that they use to maintain the relationship with tenants. Hence, it shows that the use of technology for supporting CRM is at a low level in office buildings in Sri Lanka.

4.2. ISSUES IN CRM IN FM IN OFFICE BUILDINGS SRI LANKA

A lots of CRM issues could be identified through the interviews with the respondents as they are the parties who directly face those issues. The issues identified have been summarised in Figure 1 categorising them under CRM process related, people related and technology related issues. As majority of tenants mentioned, improper behaviour of technicians is the major issue that they face with respect to CRM in FM. As mentioned, technicians behave in unsuitable ways in the tenant's place, where the tenants' customers are present. These unsuitable behaviours improper wearing, not polite to tenants' customers, making noises by over speaking with each other, which is disturbing to the occupants in that area. In Case A, the tenants have got complaints about technicians, even from their own customers. As most of the tenants pointed out, though this issue was communicated to the FM division several times, still the issue has not been totally solved. At the same time, the tenants acknowledged that, yet there are some employees who are polite and easy to work with.

Another issue faced by both the tenants and FM department is lack of communication skills and English knowledge of the employees who directly work with tenants. Though the management of Case C has arranged some English classes, it has not been successful due to the reluctance of the employees to participate to it.

Respondents of Cases A and C respectively have experienced delays in providing services and the absence of maintenance staff for reactive maintenance repairs on time. According to them, the technical staff do not consider that their jobs needs to be completed as soon as possible, thinking that it is enough to complete them within that day or within the week. However, the workers must follow their work order procedures which consumes some time so that small delays are happened. As mentioned by M3, Case C attempts to issue the work orders, relevant equipment and spare parts on time and mainly they persuade the technical team to finish the work on time to overcome these issues. According to a tenant from Case A, "Small delays of some services can be the root cause for a materialised issue" and therefore, a careful attention needs to be given to this issue since it is the responsibility of FM department to provide the tenants with required FM services on time.

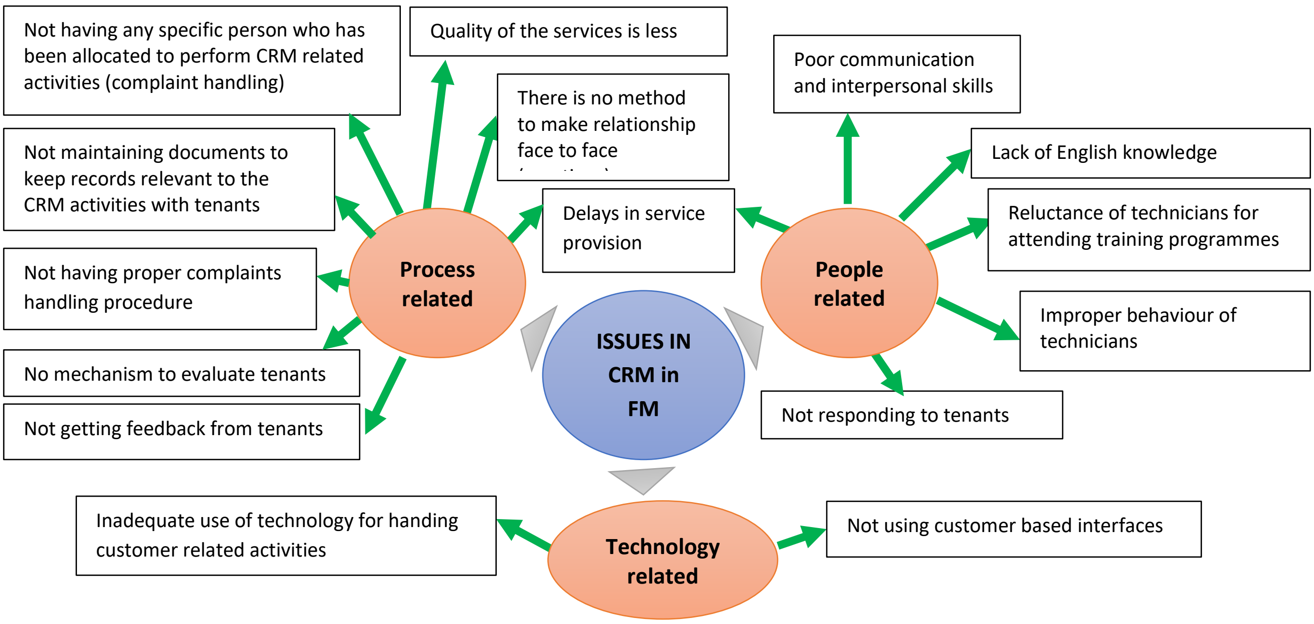

Figure 1: Issues Related to CRM in FM in Office Buildings in Sri Lanka

Moreover, most of the tenants who were interviewed pointed out that the service providers' staff do not quickly respond to telephone calls sometimes. As per the tenants of Case C, sometimes technical staff do not respond to telephone calls and they do not even call back. Then, they have to call again to remind, which is very difficult for them, when they are busy. As tenants mentioned, it is really disappointing for them if it is an emergency situation. Moreover, a tenant in Case C stated that they have not been allocated a special person to handle calls, which is a very big barrier for effective CRM. Moreover, in Case C, FM department has not provided any mechanism to give tenants' feedback to them. Although the feedback for some maintenance activities in Case A are taken via emails, there is no standardised format for it. Further, tenants who were interviewed in Case A and Case C highlighted the importance of having regular meetings with the FM department.

As most of the important information are communicated to the FM department via emails, sometimes it takes some time to take the necessary actions. The technicians are not always in the office as they are assigned different works throughout the day and therefore, in some situations, the FM division has to wait until they come back after their work. Further, the allocation of work in all the cases are done manually in all the cases consuming a huge lot of time. The study revealed that the use of technology for CRM especially when it comes to FM is at a low level in office buildings in Sri Lanka. However, as both management of tenant organisations and the FM departments highlighted, the use of advanced technology need be a priority of office buildings in Sri Lanka in order to improve the effectiveness CRM in FM.

4.3. Strategies to Overcome the Current Issues and Improve Current CRM Practices in FM in Office Buildings in Sri Lanka

The strategies to overcome the issues mentioned in section 4.2 were identified through the interviews conducted with respondents of the cases and the findings have been discussed below.

- **Developing clear procedures for CRM:** The organisation should have a clear procedure which explains how the FM department should coordinate with its tenants and the responsible parties for each task. It should also include the process that need to be followed if any issue occurred. These procedures should be communicated to FM staff as well as to the relevant personnel of the tenant organisations. When they are clear about the procedures, there will be minimal chances for misunderstandings and future issues.
- **Understanding the expectations of tenants:** The organisation should identify the requirements for healthy relationships among the FM department and the tenants of an office complex. Generally, the tenants expect the FM department to provide them with a quality and timely service. In addition, they expect friendliness, empathy, required information and good suggestions when working with tenants. There can be other needs specific to each tenant, which are required when they carry out their office activities. Therefore, first, it is required to understand the tenants and their requirements so that they can be fulfilled, leaving no chances for poor relationships.
- **Appointing a specific person for complaint handling of the tenants:** A specific person should be appointed so that all the complaints can be handled through a central point. This person can be given the responsibility to record the complaint, communicate it to the relevant party, check whether the requirement has been fulfilled and finally confirm whether the task has been completed. If such a procedure is there in the organisation, the FM employees will tend to complete their tasks timely manner and since the records are kept, they can be used as a reference source if any issue occur in future. Further, it will support effective communication among parties.
- **Getting feedback on CRM:** There should be a mechanism to get feedback from tenants after completing activities. This feedback will provide an overall idea to the FM department about the tenants' comments on the work done and it will encourage the future work. And also, this should cover the feedback on CRM of the organisation as well. If there is any negative feedback, FM department can identify the issue and prevent them from occurring in the future. Especially, when working with outsourced parties' tenants' feedback should be considered to overcome the issues that the tenants are facing. Customer satisfaction survey is one method which can be conducted to get tenants' feedback.
- **Conducting regular meetings with tenants:** Conducting meetings with tenants and the representatives from outsourced service providing organisations provide a platform for face to face discussion. Any issue related to the provision of FM services can be discussed and appropriate solutions can be decided based on the views of all the parties.
- **Implementing customer complaint handling procedure:** It is required to implement a proper customer handling procedure which records complaints, evaluate them and take corrective actions.

- **Maintaining documents:** Records on all the activities related to the service provision and other customer related activities need to be maintained for future reference purposes. Further, these information can be used as evidences as well. Specially, customer complaints and feedback related information should be maintained so that they can be analysed and appropriate decisions can be taken.
- **Providing quality FM service:** Service quality is an important aspect based on which the trust and the image of the tenants on the FM department is built. Good service quality is an enabler to build an effective relationship among parties. Generally, customer relations related issues are occurred due to the poor quality. Therefore, the FM department should always try to enhance quality of FM services.
- **Minimising the time wastage and delays of FM service provision:** As it was discussed earlier, one determinant of customer relationships is customer satisfaction, which is greatly affected by the timeliness of service. Therefore, the prevailing issue of delays need to be minimised in order to achieve effective CRM. This can be achieved by implementing a proper CRM process with appropriate technologies and by training and educating employees to complete their tasks on time.
- **Evaluating tenants:** As per the prevailing practice, there is no mechanism to evaluate the tenants. However, evaluation of tenants is important as it allows the FM department to understand their tenants. There can be some difficult tenants who always try to complain to the management even about a small issue. At the same time, there can be friendly tenants with whom, the issues can be discussed in a friendly manner and come to a decision. Therefore, understanding the nature of tenant is important when dealing with them. For example, if it will be delay completing a work at a difficult customer's place, the facilities manager can communicate it to the management of the tenant organisation beforehand so that the tenant will not get angry and complain about it. By having informal discussions with the FM employees will also help to get an understanding about different customers.
- **Organising CRM related training and development sessions for workers:** When recruiting technicians and minor staff who will be assigned to work in tenants' places, their communication skills and English knowledge also need to be considered. Further, based on the work performed by the FM employees and technicians, they should be provided with required skills and knowledge on their woks as well as CRM through training and development sessions. Further, the facilities manager should take the responsibility to motivate the staff to participate in such programmes and help them to eliminate their reluctance.
- **Changing the attitudes of in-house and outsourced staff:** In order to succeed in a business, the only way is to satisfy the customers. As the findings revealed, the tenants are largely dissatisfied with the behaviour of FM staff, especially the technicians. Therefore, it is recommended to educate the workers on the importance of treating the customers well and behave well in their office spaces. Further, the initiatives should be taken by the head of the department to encourage the staff towards this.
- **Evaluating the performance of lower level staff and giving rewards:** FM department can introduce programmes to evaluate the performance of staff related to the CRM with the involvement of HR department. Arranging small competitions among the staff members to select and reward the best staff member who maintained god customer relations will motivate the staff towards effective CRM.
- **Introducing customer-based interfaces:** Use of customer support systems which enable flexible and efficient communication among tenants and organisation is a good strategy to improve CRM. It will make the process efficient and easy for both parties.
- **Using technology for activities instead of manual procedures:** If the FM department uses advanced technology, it will help make the process efficient and easy and also save time and money of both parties. As an example, FM department can use technology for work order and feedback procedures. Further, online customer complaints forms and feedback sheets can also be introduced.
- **Organising training programmes related to the technological applications:** All the staff in FM department should be provided with necessary training related to operating computers and maintaining customer relationship via systems. Then it will be easy to maintain the relationship among both parties.

In order to ensure that these strategies are implemented, the commitment and support from the top management is required. The facilities managers or the responsible personnel of FM department need to convince the top management the need for investment on CRM in FM. Further, in order to achieve effective CRM, support of one employee is not enough. Thus, effective CRM is a collective effort all the parties in the organisation.

5. CONCLUSIONS

This study intended to study the current CRM practices in FM in office buildings in Sri Lanka, identify the issues and propose strategies to overcome them. The customers considered in this study were the tenant organisations of the selected office complexes. The literature noted that there are three key factors that affect the effectiveness of CRM in an organization: CRM process followed by the organisation, employees assigned in customer relates services and the technology used for CRM. The results were proven there are various issues associated CRM in FM office buildings in Sri Lanka, which are related to all above three factors. As the findings showed, it has not been given an adequate attention for CRM in FM, rather than just focusing on customer care practices. Hence, organsations have not implemented systematic processes for CRM and not allocated a specific employee/s specifically to handle CRM related matters. Further, handling tenants' complaints and evaluating tenants' satisfaction could also be identified as areas which are still not developed up to the required level. Incorporating technology with the organisations' CRM process is also requirement for effective CRM, which is need to be fulfilled. Several issues could be noticed regarding the employees involved in CRM as well. Among them, the improper behaviour of FM employees could be identified as a huge barrier for effective CRM. However, a noticeable attention should be given to overcome these issues in order to achieve effective CRM in FM office buildings in Sri Lanka.

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EFFECTIVENESS OF PROJECT PARTNERING IN THE SRI LANKAN CONSTRUCTION INDUSTRY

N.A.R.U. Nissanka and Mahesh Abeynayake*

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Complexity and disputes are some of the inherent features of the construction sector. Building up more effective and sustainable relationships as a means of avoiding such disputes would result in value addition to the final outcome of a project. Under these circumstances, concept of 'partnering' is emerging to play an essential role in terms of avoiding adverse relationships. The research anticipates to provide a comprehensive knowledge on reasons behind the concept of project partnering not being well practiced and its effectiveness within Sri Lanka. Quantitative research method was followed in attaining the research aim and objectives. Semi structured interviews and questionnaire survey were carried out in gathering required information for the purpose of analysis.

Information gathered via semi structured interviews revealed that project partnering is hardly or not used at all within Sri Lankan construction sector and considering current situations the need for such concept within industry is timely. Research identifies six major reasons behind project partnering not being broadly practiced in Sri Lankan context and highlights the strategies to be implemented in order to promote this concept within industry. Further suitability and effectiveness of project partnering concept within Sri Lankan context was evaluated based on the results of questionnaire survey. It revealed that time saving, increase in understanding between parties, less adversarial relationships as well as high customer satisfaction are highly possible if this is implemented in Sri Lanka. Further it highlights the government has a major role in identifying this concept and promoting it throughout the industry.

Keywords: *Commitment; Construction Industry; Customer Satisfaction; Disputes and Conflicts; Mutual Benefits; Project Partnering; Trust-based Relationships.*

1. INTRODUCTION

Industries in which inter organizational relationships are playing an essential role in enhancing the business, it is important to build sustainable relationships and in order to build that relationship, parties involved should shift from low trust base to high trust base environment (Wood et al., 2002). In different countries the construction industry has attracted many criticisms for the existing relationships between parties due to the defects, poor collaboration, lower customer focus and lack of end user involvement (Egan, 1998). May be due to the criticisms that were there in traditional procurement and project governance, the interest on collaborative relationships (most of the times referred to as partnering) has increased over the recent years as an alternative to traditional approach (Eriksson et al., 2008).

Partnering is identified as a concept which basically provides a solid framework to establish the mutual objectives of parties involved in a project and a better dispute resolution procedure as well as it encourages the concept of continuous improvement (Naoum, 2003). There are mainly two types of partnering. One form basically involves strategic and long-term relationships with commitments and the other form is specifically for a particular project (Cheng et al., 2004). Rameezdeen and Silva (2002) have identified that partnering has just started to emerge within Sri Lankan construction sector. Hence there can be different issues in initiating this concept with construction projects and even if the concept has been initiated the effectiveness of it would be questionable. In such circumstances, carrying out a critical study on effective project partnering in Sri

*Corresponding Author: E-mail – abey92@hotmail.com

Lankan construction industry is timely. Therefore the research is focused to identify why this concept, project partnering, is not being well practiced currently in the construction sector of Sri Lanka and to evaluate how effective the project partnering can be within Sri Lankan construction industry.

The paper structure begins with a literature review on construction project partnering and its benefits, critical success factors and problematic areas. The paper then presents methodology adopted for this study and discuss findings on the reasons behind project partnering not being well practiced and effectives of it within Sri Lanka. Finally, the paper is concluded by summerising the findings.

2. LITERATURE REVIEW

A comprehensive literature review was carried out to identify the concept of project partnering, its benefits, partnering process and problematic areas.

2.1. PARTNERING STRATEGY

In between 1970s and 1980s, the whole businesses within the construction industry changed dramatically due to the impact of various economic factors, mainly due to the increasement of inflation rate (Cook & Hancher, 1991). Under these circumstances, the construction industry had to adopt new innovative strategies in order to overcome all these challenges and develop more into the future (Gardiner & Simmons, 1998). Hence to respond these challenges and for the betterment of construction sector, the concept of "partnering" had been introduced as an innovative procurement strategy to mitigate the risks associated with investments and reach to a win-win situation for both contracting organization and the Client (Cook & Hancher, 1991). Various definitions for the concept of partnering can be identified in different literatures (Eriksson, 2010). Basically there is no accepted definition for 'partnering' and it generally refers to different managerial practices as well as different organizational designs that would enhance the relationships (Barlow & Jashapara, 1998). Whereas by referring these various definitions the following can be constructed.

"A commitment of two or more organizations in order to achieve specific mutual objectives and working together to improve performance and establish continuous improvement by sharing the gains (win-win situation)".

Project partnering is one of the main concepts that can be discussed under the partnering concept. This is basically focused on a particular project only (Lu & Yan, 2007). Further, this is the commitment of project team of a particular project in order to achieve the common set of project goals by working together along with established dispute resolving procedures in an effective way (Bygballe et al., 2010). Hence project partnering can be considered as 'result-oriented' mechanism (Cheng et al., 2004). Many organizations will first select project partnering as a means of getting the project done and wait for the positive results before implementing 'strategic partnering' for the future projects (Matthews et al., 1996).

2.2. BENEFITS OF PROJECT PARTNERING

Numerous advantages can be seen with the implementation of project partnering strategy. According to the survey results of Black, Akintola and Fitzgerald (2000), some advantages attributable to partnering were identified. These advantages are shown in the following Table 1.

Table 1: Benefits Attributable to Partnering

Benefits	Total	Involvement	Non-involvement	ANOVA	
				F statistics	Significance level
Less adversarial relationship	4.37	4.49	4.12	2.47	0.37
Increased customer satisfaction	4.19	4.38	3.80	5.94	0.07
Increased understanding of parties	3.99	4.15	3.64	4.78	0.53
Improved time scale	3.92	4.13	3.48	6.08	0.42
Reduced risk exposure	3.91	4.02	3.68	1.60	0.11
Reduced cost	3.81	3.96	3.48	2.88	0.08

Improved administration	3.73	3.81	3.56	1.04	0.33
Quality improvements	3.69	3.74	3.60	0.23	0.98
Improved design	3.55	3.68	3.28	2.43	0.25
Design cycle reduction	3.38	3.47	3.20	1.23	0.21

Source : Adapted From (Black *et al.*, 2000)

According to Black et al. (2000) one of the major features that can be identified from the partnering under a project is the advantage of being able to share the risks as well in a case of partnering with a firm under an international project most of the cultural and language barriers can be overcome successfully.

2.3. PROJECT PARTNERING PROCESS

Adopting the right and accurate project partnering process may be required in order to achieve project objectives and goals. Cheng and Li (2002) have identified a customized model for the project partnering process. According to Cheng and Li (2002) the process comprises of mainly three stages namely partnering formation, partnering application, partnering completion and reactivation. Also each stage requires common and functional success factors in order to achieve the success.

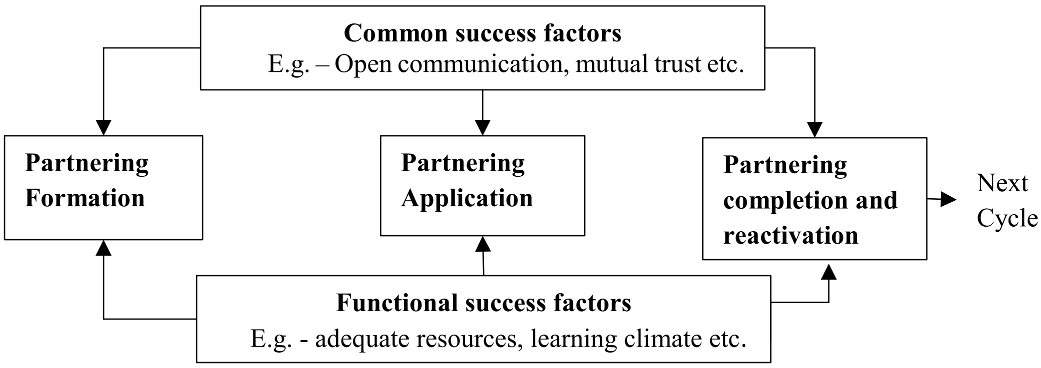

Figure 1: Customized Model for the Project Partnering Process

Source: (Cheng & Li, 2002)

The common success factors mentioned in the above process are common for all three stages. Whereas the functional success factors are unique for each stage. For an example, as identified by Cheng and Li (2002), partnering formation stage requires team building while partnering application stage requires adequate resources, joint problem solving and so on as the functional success factors.

In the *partnering formation stage* explicit or implicit agreements shall be made between key parties to the construction project to accomplish mutually agreed goals and objectives (Cheng & Li, 2002). Also unfreezing of minds of parties may be required to accept the need for change and to identify need for project partnering concept. During the *partnering application stage* execution of partnering concept among parties to the project shall be done (Cheng & Li, 2002). Learning and getting experience regarding the partnering concept implemented will also be done at this stage. *Completion and reactivation* simply means after completing the current project the intention of parties to rerun the informal relationships with same parties in a new project (Cheng & Li, 2002).

2.4. CRITICAL SUCCESS FACTORS FOR CONSTRUCTION PROJECT PARTNERING

Many studies have revealed different types of Critical Success Factors (CSFs) and if major parties to the project do not pay a greater attention to these CFSs, painful as well as disruptive results can be visible (Cheng & Li, 2001). Chan et al. (2004) identified main seven significant factors affecting the partnering success. They are adequate resources, support from top management, mutual trust, long term commitment, effective communication, effective co-ordination and productive conflict resolution.

Moreover, based on the data collection and analysis of the studies of Cheng and Li (2002) different common and functional success factors, which are related to each stage of partnering process, could be identified. Top management support, mutual trust, open communication and effective co-ordination are the common factors highlighted under each stage of project partnering process. Functional critical success factors vary with each stage of the process.

Furthermore, according to the survey data analysis of Black, Akintoye and Fitzgerald (2000), the most important factors that contribute to construction project partnering success are mutual trust, effective communication, commitment from senior management, clear understanding among parties, acting consistent with objectives, dedicated team, flexibility to change and commitment to continuous improvement.

2.5. PROBLEMATIC AREAS OF PROJECT PARTNERING

The following were identified as the problematic areas of construction project partnering.

1. **Misunderstanding of partnering concept**

An unambiguous understanding as well as the knowledge regarding the project partnering concept is vital to achieve success in partnering relationships between parties involved in the project (Chan et al., 2003). Moreover according to Larson and Drexler (1997), it is the limited experience in project partnering that has affected the understanding of partnering concept.

2. **Relationship problems**

One of the basic objectives of project partnering is to encourage the parties involved in the project to shift from traditional adversarial attitude to more co-operative as well as team based approach in order to prevent issues (Loraine, 1994). Further according to Loraine (1994), many parties tend not to trust other parties due to past experience and fear towards the change. Relationship management is considered as an umbrella concept under the partnering and failure to comply with it might cause damages to good business relationships (Manley, 2002).

3. **Cultural barriers**

Compared to the very traditional culture of construction projects, projects with partnering will have different cultural features (Chan et al., 2003). Further many organizations are generally reluctant to change into a more integrating culture. According to Hellard (1995), it is basically difficult to change the established culture within an organization. Hence compatibility of culture is one key element to be considered when selecting a partner for the project (Eriksson et al., 2009).

4. **Uneven commitment**

Implementing project partnering requires a greater commitment from each party involved in the construction project (Chan et al., 2003). According to the Sanders and Moore (1992), all involved parties in the project should need to have total commitment towards the project partnering process. Whereas it is visible some uneven level of commitment in practice mainly due to different goals among parties in the project (Eriksson, 2010). All these contracting parties should require to have more effort to balance the commitment from each side (Chan et al., 2003).

5. **Communication problems**

In order to fully understand the client's requirements, effective as well as clear and open communication is mandatory (Chan et al., 2003). According to Larson and Drexler (1997), regardless of the importance of direct open communication in partnering, some parties do not trust other party and not willing to communicate and share important information. Sometimes failure in effective communication can result in less collaboration between parties involved in project (Gardiner & Simmons, 1998).

6. **Lack of continuous improvement**

According to the Sanders and Moore (1992), traditional effort for the continuous improvement, as a joint effort, is basically required to eliminate waste and barriers. Main barriers found in this effort to improve continuously are approval time and development costs (Chan *et al*., 2003). Focusing on continuous improvement will enable the parties involved in the project to enhance quality and add more value to the final outcome (Stehbens *et al.*, 1999).

7. Insufficient problem solving

Sanders and Moore (1992) mentioned that problems do not disappear automatically just by writing the partnering agreement. Conflicts and disputes among the parties involved in the projects are still possible (Ng *et al*., 2002). Even if project partnering team is willing to recognize and solve all the issues, still the problems can occur (Albanese, 1994).

8. Insufficient efforts to keep partnering going

Initiating the partnering process requires additional staff, cost as well as resources and project partnering further requires constant effort to maintain good relationships throughout the project (Chan *et al*., 2003). As identified by Sanders and Moore (1992), parties involved in the project can easily get back to the routine traditional way of working just by ignoring the partnering concept.

9. Discreditable relationship

Partnering procedures will provide various benefits to the construction sector such as better relationships, better performance, innovation and so on (Chan et al., 2003). However according to Newman (2000), these improved relationships can lead to corruption. Moreover Longstaff (2000) identified the importance of having an independent ethics audit in order to define the values and principles of the company as well as involved parties to avoid these issues.

3. RESEARCH METHODOLOGY

Survey method was used for this particular research. Under the survey approach, semi structured interviews and questionnaire survey were conducted for the data collection purpose. Mainly the views regarding reasons behind project partnering not being well practiced and the strategies to be implemented in order to promote the concept within Sri Lankan construction industry were identified during semi structured interviews. Further opinions of experts were taken regarding the suitability and effectiveness of project partnering for the development of construction industry. Five experienced professionals were selected for the interview survey. The questionnaire survey was developed based on the literature findings and mainly based on the data collected via semi-structured interviews. Then findings questionnaire survey were analysed using Relative Importance Index and standard deviation.

Total 44 questionnaires were distributed among selected professionals and only 36 questionnaires had been received which is equal to 81.8% response. Further questionnaires were distributed among contracting organizations and consultancy organizations. Out of all the respondents, 30.6% (11 Nr) of respondents were working in contracting organizations while the rest of 69.4% (25 Nr) were related to consultancy organizations. Service experience level of each respondent to questionnaires was categorized into few sections as below.

The target population for this particular research was the professionals working in the construction sector of Sri Lanka. More consideration had to be given for the fact that the projects which actually involved project partnering concept within Sri Lanka are very minimal. The selection of sample for this study was based on non-probability sampling.

Table 2: Service Experience Level Category of Each Respondent

	Frequency	Percent
0-5 Years	6	16.7
6-10 Years	11	30.6
11-15 Years	11	30.6
16-20 Years	3	8.3
20 Years <	5	13.9
Total	36	100.0

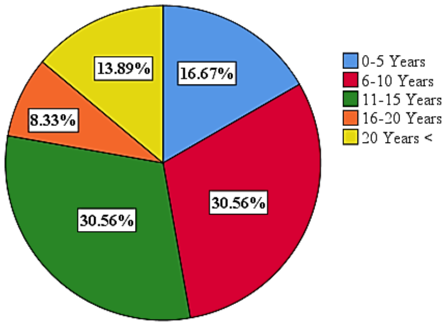

Figure 2: Service Experience Level Category of Each Respondent

4. DATA ANALYSIS AND DISCUSSION

Data collected via semi structured interviews and questionnaire survey has been summarized below.

4.1. *APPLICABILITY AND EFFECTIVENESS OF PROJECT PARTNERING CONCEPT WITHIN SRI LANKAN CONSTRUCTION INDUSTRY*

All the views taken under the semi structured interview survey confirmed that this concept is not practicing within Sri Lanka broadly. Whereas in some instances project partnering concept can be seen practicing at very minimal level in an unofficial manner. Partnering concept is still new to the construction industry of Sri Lanka.

This broader concept is very suitable for the construction industry of Sri Lanka even though its application is at very minimal level at present. Considering all the possible benefits from this concept within Sri Lankan construction sector, effectiveness of the outcome is very significant. When the risks and ultimate gains are shared among parties, both the main parties will be working towards achieving each other's goals and thereby final outcomes and processes of achieving the outcomes will be very effective. Whereas the views of the most respondents highlighted that in order for the project partnering concept to be more suitable and its outcomes to be more effective, first the mindset and the attitude of parties working in Sri Lankan construction sector must be altered. Basic foundation must be laid by constructing a more positive mentality, essentially a more spiritual development, within most of the executive level parties involved in the construction industry of Sri Lanka before implementing the concept.

4.2. *REASONS BEHIND PROJECT PARTNERING NOT BEING WELL PRACTICED WITHIN SRI LANKAN CONSTRUCTION SECTOR*

Main reasons identified as to why project partnering concept is not well practiced within Sri Lankan construction sector are summarized below. These reasons were mainly identified as part of the semi-structured interviews.

Table 3: Reasons Behind Project Partnering Not Being Well Practiced in Sri Lanka

Number	Reason
1	Contractors are not up to the required level to implement a concept like project partnering (i.e. not willing to share the risks)
2	Clients may approach only few large contracting organizations if they need to go for the project partnering.
3	Clients and contractors in the industry are so much used to conventional approaches (traditional methods) other than partnering.
4	Contractors and clients may not willing to adopt concepts which are new to the industry (i.e. Project partnering)
5	Larger contractors have enough projects using conventional methods and hence they are not bothered to implement a collaborative approach like partnering.
6	Clients and contractors do not see the importance and benefits of project partnering (they see it as just another way of getting the project completed) and hence not focused on this concept.

According to views of interviewees, most of the contractors and clients are so much used to conventional approaches of getting the project done. For an example, most of the times in Sri Lanka, clients tend to use traditional (integrated) procurement path as well as design and build (separated) approach. Further most of the respondents to semi-structured interviews mentioned that contractors also, most of the times, prefer to have these traditional approaches in place when implementing projects. Now these parties are very much used to the traditional approaches and hence they are not interested on involving in this concept. Since the contractors, in Sri Lankan construction sector, are very much familiar with the traditional methods it is easy for them to carry out all the work related to any project under the known circumstances compared to a project in which the project partnering concept is involved.

Further, several interviewees stated by explaining their ideas, fear of adopting the project partnering concept is there within parties involved in construction sector. Clients and contractors might not willing to take any risk by approaching a concept which is new to the Sri Lankan construction sector. Further there is enough risks and disputes involved in construction projects. Hence due to all the risks already exist, specially contractors might not willing to implement a novel concept like project partnering and rather they would continue all the projects using more familiar conventional approaches.

In addition, respondents of semi structured interviews emphasized that most of the contractors might see this concept as just another way of getting the project done. They do not see the importance and benefits that can be gained by all the parties involved in a construction project if the concept of project partnering is implemented. Contractors and clients essentially see this approach as a method of getting the main two parties to a project together and complete the project may be with lesser disputes. Whereas both these main parties may prefer to use the conventional approaches even with lesser additional disputes rather than going for an unfamiliar concept.

Moreover required qualities and appropriate mindset must be there within contractors. In Sri Lankan context (as per the views and ideas of most of the interviewees), some contractors mainly concerned about finishing the job soon, get the money and quickly go for another job. Building up more constructive relationships and adding more value to the work that they are doing is not often seen within Sri Lankan construction sector. Basically the capacity to accept the required risk level and the ability work collaboratively based on a trust-based platform are lacking when looking at some of the contractors working in the industry. The identified (under semi structured interviews) below mentioned reasons were taken into the consideration of professionals working in construction industry via semi-structured interviews and ranking of each reason was done as below.

Table 4: Ranking of Reasons Identified

Reasons	Mean rating	Std. Deviation	RII	Rank
Clients and contractors in the industry are so much used to conventional approaches (traditional methods) other than partnering.	4.64	0.487	0.92	1
Contractors and clients may not willing to adopt concepts which are new to the industry (i.e. Project partnering)	4.50	0.737	0.91	2
Contractors are not up to the required level to implement a concept like project partnering (i.e. not willing to share the risks)	4.06	0.860	0.82	3
Clients and contractors do not see the importance and benefits of project partnering (they see it as just another way of getting the project completed) and hence not focused on this concept.	4.03	0.910	0.81	4
Larger contractors have enough projects using conventional methods and hence they are not bothered to implement a collaborative approach like partnering.	3.89	0.820	0.78	5
Clients may approach only few large contracting organizations if they need to go for the project partnering.	3.75	0.906	0.74	6

4.3. BENEFITS OF PROJECT PARTNERING RELATED TO SRI LANKAN CONSTRUCTION SECTOR

These benefits were identified under the literature review and brought under the consideration of each professional via questionnaires to identify how far each benefit is achievable within Sri Lankan construction sector if this concept is broadly implemented. Following table demonstrates the mean rating and standard deviation calculated for each benefit. Based on these information RII was calculated and ranking of benefits was done accordingly.

Table 5: Ranking of Benefits of Project Partnering in Sri Lanka

Benefits	Mean rating	Std. Deviation	RII	Rank
Time saving	4.31	0.710	0.86	1
Less adversarial relationships	4.14	0.351	0.83	2
Increases the understanding between parties	4.11	0.747	0.82	3
Increases customer satisfaction	4.00	0.676	0.80	4
Reduces the cost	3.94	0.715	0.79	5
Improves designs	3.92	0.500	0.78	6
Improves the quality	3.78	0.422	0.76	7
Improves project administration	3.75	0.649	0.75	8
Design cycle reduction	3.64	0.723	0.73	9
Reduces the risk exposure	3.50	0.941	0.70	10

The results clearly demonstrate that 'time saving' (with RII of 0.86) is the most possible and achievable benefit within Sri Lankan construction sector if this concept is broadly implemented. Further above analysis highlights that less adversarial relationships (with RII of 0.83), increase in understanding between parties (with RII of 0.82) and increase in customer satisfaction (with RII of 0.80) are some of the other important benefits which are more likely to be achieved when it comes to Sri Lankan context. Moreover the above table 4 further demonstrates that it is quite difficult to reduce the risk exposure (with RII of 0.7) and design cycle (with RII of 0.73) with the implementation of this concept within Sri Lanka. This may be probably due to the inherent features of Sri Lankan construction sector.

4.4. Potential Strategies to Enhance the Successful Implementation of Project Partnering within Sri Lankan Construction Sector

Five main strategies were identified from the different views of each respondent of semi-structured interviews to enhance the implementation of project partnering concept within Sri Lankan construction sector.

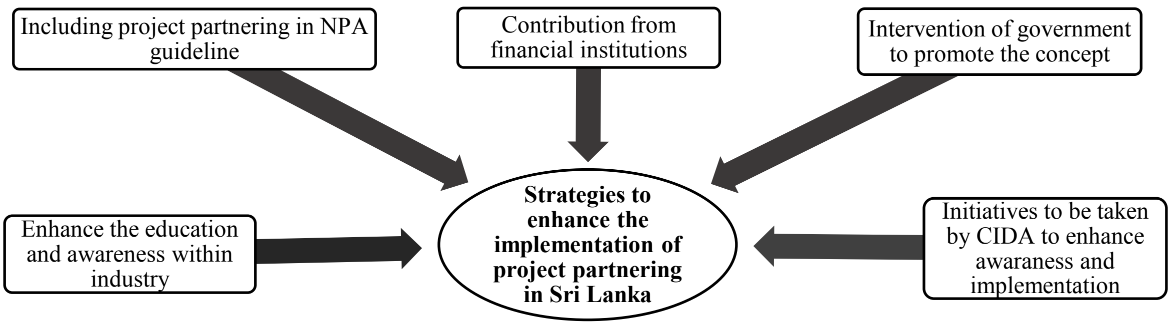

Figure 3: Strategies to Enhance the Implementation of Project Partnering in Sri Lanka

If government takes the initiative to implement this concept in government projects, contractors will also get the opportunity gain experience and it will assist to enhance the awareness within private sector regarding this approach. Further tax reliefs and other concessions can be given by the government for the projects which involved project partnering as the procurement path. As part of the government's initiatives in promoting this strategy within Sri Lanka, it can complete few projects successfully (as the first step) using this concept as the procurement method and demonstrate the effective and positive results to the private sector. This way professionals in private sector will accept the positive side of it and with the concessions given these organizations will tend to adopt this concept within new upcoming projects. Apart from all these steps, government can bring the examples from successfully completed foreign projects (using project partnering) from different countries and demonstrate how effective and useful this concept can be for the development of Sri Lankan construction sector.

Construction Industry Development Authority (CIDA) is the ideal party to take the initiatives under the government of Sri Lanka to promote and enhance the implementation of project partnering concept. CIDA can provide standard forms and specimens for partnering charter suitable for the projects which involve partnering concept. The concept of project partnering and the specific process that should be followed under this approach can be included in the National Procurement Agency (NPA) guideline. This a better way to make the contractors and clients more familiar with this concept. Currently, in Sri Lanka, one major reason behind partnering not being well practiced is that unfamiliarity or unawareness of this concept. Hence the respondent highlighted that by including the above said areas in NPA guideline, unawareness and unfamiliarity can be eliminated up to a considerable level.

Financial institutions, such as banks, can also contribute to the broader implementation of partnering concept. Basically investors tend to raise the required funding mainly either via equity capital or debt capital. When a potential investor approach a bank to raise the debt capital (mainly by taking a long term loan), basically the financial institution will first look at the risk level involved in lending out huge amount of money as a long term loan. The risk level (with lesser disputes and all the benefits related to this concept as a procurement path) involved, in projects which basically involved project partnering, is comparatively low. Hence banks will have a positive mind in lending more money for these types of investments which basically involves partnering strategy. In order to get the above highlighted point more realistic, it is a must to educate or make the financial institutions aware about this concept and its benefits. Then those institutions will realize that how lesser risky it is to lend money for investors who seeks to invest on projects under the project partnering concept as a procurement method. Further investors will be able to negotiate with banks and raise the debt capital at a comparatively lesser interest rate. Further the respondent emphasized financial newspapers can be used as an important tool to provide good knowledge about this particular concept to the financial institutions.

One of the other important strategies to enhance the implementation of partnering concept is that educate and develop the required mindsets of the parties involved in construction projects in Sri Lanka. As described in previous sections, some reasons behind partnering not being well practiced within Sri Lanka are the unawareness and difficulty in building up required mindset within people. As clarified with the aid of respondents' views, spiritual development in mindsets to work more collaboratively based on a trust-based relationship is vital to enhance the implementation of partnering concept and sustain within that environment.

5. CONCLUSIONS

Disputes and conflicts are some inherent features of construction sector. Building up more effective and positive relationships under these circumstances would result in higher value addition to the final outcome of a project. Project partnering is identified as one of the ideal concepts to build up effective and trust-based relationships between parties involved in construction projects.

Project partnering concept is not broadly practicing (or not practicing at all) within Sri Lankan construction sector. Further six major reasons were identified as to why this concept is not broadly practicing within the country. Sri Lankan construction sector is very much used to conventional or traditional approaches other than concepts like partnering was the main reason identified. In addition, some main strategies were identified in order to enhance implementation of project partnering concept within Sri Lanka. Under this, it was highlighted the essential role of Sri Lankan government and the CIDA to be played in promoting the concept within country. Further important contribution from financial institutions was highlighted in enhancing the implementation of project partnering concept in Sri Lanka.

When it comes to Sri Lankan context time saving, less adversarial relationships and increase in understanding between parties are the most achievable benefits if the concept of project partnering is implemented broadly. Moreover it revealed that uneven commitment from each party involved, relationship problems and failure to understand the partnering concept and what is actually required under this strategy are the most likely issues which could lead partnering to an unsuccessful situation within Sri Lanka.

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EMBODIED CARBON EMISSIONS OF BUILDINGS: A CASE STUDY OF AN APARTMENT BUILDING IN THE UK

Nirodha Gayani Fernando[1*], Damilola Ekundayo[1] and Michele Florencia Victoria[2]

[1]School of the Built Environment, University of Salford, United Kingdom

[2]School of Architecture and Built Environment, Robert Gordon University, United Kingdom

ABSTRACT

The UK government has set a target to significantly reduce UK greenhouse gas emissions by 2050. 47% of all UK CO2 emissions are linked to the construction and operation of the built environment. Buildings emit two types of carbon namely operational carbon (OC) and embodied carbon(EC). Operational carbon is regulated in the UK as it contributes up to 70-80% of total emissions. Further, EC reduction is top priority with the rise of demand for zero carbon buildings and EC is unregulated at present. EC can be controlled by vigilant building designs, selection of low carbon materials and technologies. Estimating EC of building will provide better understanding of the carbon significant elements and enable designers to make informed decisions. Accordingly, a case study of an apartment building located in Sunderland in the UK is selected for the study. EC estimates were prepared using priced Bill of Quantities of the building and carbon blackbook. Then, the building elements were classified as per BCIS (Building Cost Information Services) element classification and the carbon significant elements were identified in the case study building. Frame was identified as the most carbon significant element. External walls including windows and doors, upper floors, substructure, internal finishes, roof and internal walls & partitions were identified in descending order of carbon significant elements. Further, comparative analysis of EC between an apartment building and an office building was conducted. The office building carbon significant elements were found to be different from that of an apartment building. Findings of the case study building can inform designers about the elements that has an immense reduction potential and worth investing in low carbon technologies and materials. However, the findings are based on a single case study and, hence, cannot be generalised but can be seen as an exemplar for further research.

Keywords:*Apartment Building; Building Elements; Carbon Significant; Embodied Carbon.*

1. INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC, 2014) report states that continued emissions of carbon will lead to a drastic change in climate and increase in temperature by 1.5 °C – 2 °C by the end of the 21st century. Therefore, it has become an utmost priority in the world to reduce carbon emissions (Chau *et al*., 2015). Further to the Kyoto protocol and then the Paris agreement by UNFCC in 1998, 2012 and 2016 respectively, building sector was identified as an inevitable sector with regard to its high emission contribution and high emission saving potential in the short term. According to Royal Institution of Chartered Surveyors (RICS, 2014), low carbon building transition plans started all around the world allowing most of the developed and developing countries to reduce the operational carbon emitted from buildings through increasing operational energy efficiency. However, it caused the proportion of embodied carbon in the total carbon emission of buildings to increase. With the recognition of that, the attention of environmentally advanced developed countries has now shifted towards reducing embodied carbon emissions of buildings (RICS, 2014). Building sector is known to be one of the largest contributors to the global carbon emissions. It is responsible for more than one- third of total energy use and 30% of global carbon emissions (Peng, 2015).

*Corresponding Author: E-mail – N.G.Fernando1@salford .ac.uk

Embodied Carbon is the total greenhouse gas (GHG) emissions (often simplified to "carbon") generated to produce a built asset (UK Green Building Council, 2017). This includes emissions caused by extraction, manufacture/processing, transportation and assembly of every product and element in an asset. In some cases, depending on the boundary of an assessment, it may also include the maintenance, replacement, deconstruction, disposal and end-of-life aspects of the materials and systems that make up the asset (UK Green Building Council, 2017). Energy use in residential in the UK accounts for 27 percent of carbon emissions. Therefore, improving energy efficiency and using renewable energy in housing stock presents a great opportunity to contribute towards the 2050 target of an 80 per cent reduction of greenhouse gas emissions. In 2007 the UK government proposed tightening building regulations to achieve the carbon reduction from residential sector - first by 25% in 2010, and then by 44% three years later. However, it is not yet achieved due to numerous barriers. This paper attempts to identify the possibility of estimating embodied carbon emissions of apartment buildings in the UK, so that necessary actions can be taken to manage the environmental impact of buildings and therefore increase the awareness/significance of embodied carbon counting. The paper also explores and compares the embodied carbon of an apartment building with that of an office building in the UK.

2. EMBODIED CARBON

A building emits two types of carbon during its life cycle, i.e. operational and embodied carbon (RICS, 2014). Operational Carbon (OC) is the emission generated during the operational phase of a building as a result of the operational energy used for heating, cooling, ventilation, lighting, ICT equipment, cooking and refrigeration appliances etc. (RICS, 2014). Embodied Carbon (EC) is 'Carbon emissions associated with energy consumption (embodied energy) and chemical processes during the extraction, manufacture, transportation, assembly, replacement and deconstruction of construction materials or products' RICS (2014, p. 5). EC emission during the lifetime of a building is shown in Figure 1. EC can be categorised into three types such as Initial EC (raw material extraction, manufacturing, transport and construction), recurring EC (in-use EC such as repair, maintenance and replacement) and Demolition EC (EC during demolition). EC can be minimised due to recycling of scrap materials or products after demolition.

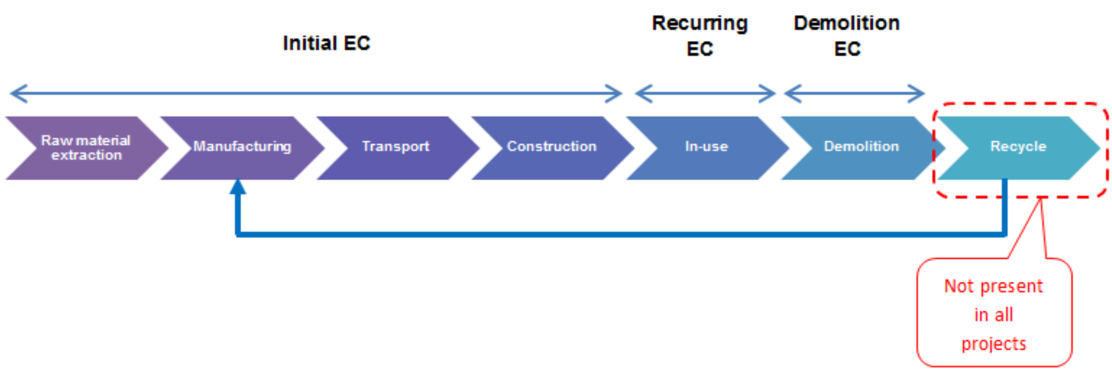

Figure 1: EC in a Building Life Cycle

Source: Victoria *et al.* (2015)

According to RICS (2014), EC emissions are calculated from cradle (earth)-to-gate, cradle-to-site, cradle-to-end of construction, cradle-to-grave or cradle-to-cradle stages (See Figure 2). There are many EC datasets available in the UK (Hammond & Jones, 2011a). Hammond and Jones (2011b) and Sansom and Pope (2012) highlighted that many embodied carbon datasets available are cradle-to-gate and they opined that it can be unsuccessful to include emissions from later stages of life cycle (such as construction, operation & maintenance and demolition & disposal) due to project specific emissions. Mode of transport and type of fuel also plays a significant role, in reducing carbon emissions, other than the distance of travel (RICS, 2014; Sundarakani *et al.*, 2010).

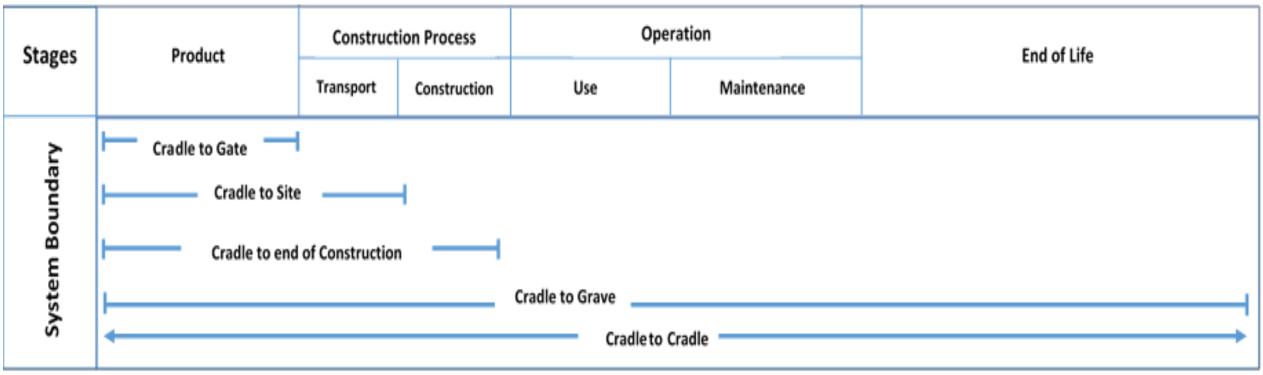

Figure 2: System Boundaries of EC Estimation

Adapted from: RICS (2014)

According to Figure 3, approximately 80% of initial EC can be reduced before construction commenced (Asiedu & Gu, 1998). As more carbon is committed into the project, the reduction potential decreases rapidly as possible design solutions are constrained by previous design decisions. Then, during construction phase, the reduction potential can be considered as nearly zero unless there is a design change. Therefore, EC reduction action has to be considered during the initial stage of a project before construction commences. In order to reduce EC in a project, careful investigation is essential to identify the most carbon intensive elements and materials used for those elements. Accordingly, this study was conducted to identify the EC intensive building elements and materials used for those elements.

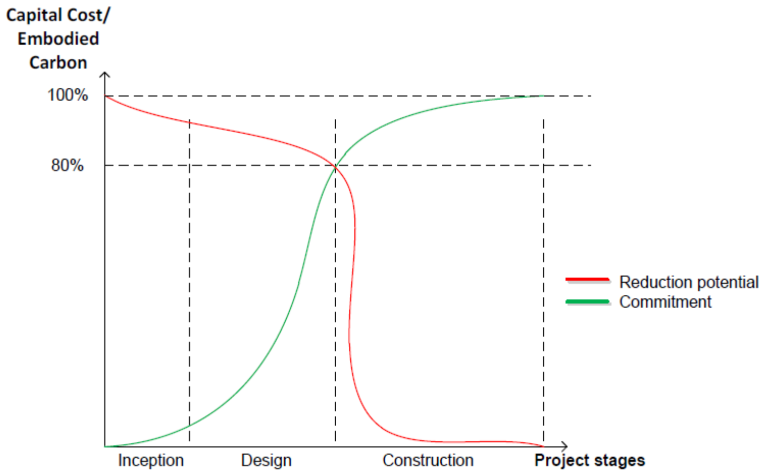

Figure 3: EC over Project Stages

Source: Victoria *et al.* (2015)

3. RESEARCH METHOD

Research approaches can be mainly categorised as quantitative, qualitative and mixed approaches. According to Fellows and Lui (2003) quantitative approach is inclined to collect factual data and to study relationships between facts and how such facts relate to theories and the findings of any research executed previously. The study analysed the embodied carbon of an apartment building located in Sunderland, UK. Hence, quantitative approach has been selected for the study as the most suitable approach as the study intends to collect factual data. An apartment building has selected as a case study and this provides an in-depth enquiry of the research problem. Furthermore, Yin (2009) found that case studies would provide an opportunity to gain holistic view of the research problem. This approach also helps to understand and explain a research problem or situation

(Baxter & Jack, 2008). Hence, the justification for the single case study approach used in this paper and subsequent research in this area can build on this work.

The main building elements such as substructure, frame, upper floors, roof, external walls, internal walls & partitions and internal finishes were considered to calculate the embodied carbon in the study. The selected elements are compliant with BCIS element classification. This study was limited to the cradle to gate system boundary for a residential and a commercial building, and not all building elements were selected due to resource constraints including data availability. The details required to calculate the embodied carbon were obtained from priced Bills of Quantities (BoQs), and technical specifications of the case. Building Blackbook was used to calculate the embodied carbon of building elements. This is one of the limited available resources produced in BoQ format for calculating building embodied carbon (Franklin & Andrews, 2011).

Firstly, building items of works from BoQ were identified for each work section. After that, the building blackbook was used to calculate each work item's embodied carbon. The following formula has been used to calculate the total EC for each element.

$$CO_2 \text{ embodied of an element} = \sum_1^i CO2 embodied\ of\ a\ BoQ\ item, i \qquad \text{Eq. (01)}$$

Here;

CO_2 embodied of an element is embodied carbon of an element

CO_2 embodied of BoQ item *i* is the amount of embodied carbon of the *i* th BoQ item in the building

4. RESEARCH FINDINGS

The building studied is a three-storey apartment building in Sunderland, UK. The newly constructed building has a reinforced concrete structure, L shape building and it includes three floors. Ground floor and first floor have 6 flats each and the second floor has 5 flats. There are three lifts in the building. The main characteristics of the case study building are given in Table 1.

Table1: Characteristics of the Case Study Building

Building Parameter	Specifications
Building area	1425.32 m^2
No. of floors	Three- storey apartment building
Foundation	Pad foundation with Reinforced in situ concrete Grade C35, 20mm
Frame	Streel frame and concrete
Upper floors	In situ concrete grade C35 with A193 mesh reinforcement, to holorib decking
External walls	Cavity wall brick and blockworks- Engineering brickwork, Class B, mortar (1:4), stretcher bond, half brick thick external face of external wall. Concrete blockwork, 7N/mm^2 compressive strength, mortar (1:4), 140mm thick internal face of the external wall
Internal walls	Gyproc Gypwall metal stud partition system as K10-129
Roof	Pitched roof 40^0 angle, Interlocking concrete roof tiling, Marley Modern, 50x25mm battens, metal roof cladding tile support panel system, H65-120
Internal finishes	Wall lining, 12.5mm thick plasterboard fixed to blockwork with adhesive dabs, 3mm thick plaster skim coat finish Quarry tiling, 150 x 150 x 12mm units, fixing with approved adhesive, white grout, concrete surfaces Fitted carpeting, basic cost £20.00/m^2, adhesive taped joints, laid loose on and including approved underlay, concrete surfaces Suspended ceiling system lay in grid 600 x 600mm in Trulok 24 grid Armstrong Dune Max Tegular K40 - 115

The embodied carbon content of a three-storey apartment building was considered as the case study and the implications of the results were discussed in this section.

Table 2 presents the elemental EC and EC per Gross Internal Floor Area (GIFA) of each element of the building. As per RICS (2012), GIFA is used as a standard metric for benchmarking, estimating, and cost planning purposes in the construction sector. It is a clear measure for comparison across all buildings regardless of their function, design or specification. Therefore, EC per GIFA of the elements of this building was also calculated for the purpose of comparison with other studies.

Table 2: Embodied Carbon of Each Building Element

Building Element	Total EC	EC per GIFA	% of total EC
Substructure	900,180.07	631.56	13.72
Frame	1,470,573.79	1,031.75	22.42
Upper Floors	958,598.86	672.55	14.62
Roof	263,800.08	185.08	4.02
External Walls including Curtain Wall, External Windows and Doors	1,163,574.24	816.36	8.02
Internal Walls & Partitions	50,670.29	35.55	0.77
Internal Finishes Including Floor Wall and Ceiling Finishes	587,885.94	412.46	8.96

The findings revealed that frame emits 1031.75 of EC $kgCO_2/m^2$, placing it on the top of the elemental embodied carbon emission hierarchy of this case study. This is mainly due to the heavy use of steel and concrete (two types of high carbon intensive materials) in the frame compared to other elements. The remaining elements such as external walls including external doors and windows, upper floors, substructure, internal finishes, roof, and internal walls and partitions place respectively in the hierarchical order. Further, Table 3 presented the different items included in the "frame" element and the embodied carbon of each item. According to Table 3, structural steel frame identified as the highest EC among other components in the frame. Main reason is steel is a major carbon hotspot.

Table 3: Items Included in the Frame

Components included in the Frame	EC- $kgCO_2$
Structural Steel Frame	893,772.744
Timber Glulam beams to Main Entrance Foyer and Main Hall	25,088.660
Connections between steel and Glulam Structures	85.897
Fire protection Intumescent paint to steel members to give 1Hr protection	
203x203x52UC columns	164,747.544
406x178x54UB columns	18,039.802
Underside of first floor or roof slab	
178x102x22 UB	19,012.963
254x102x22 UB	29,038.706
305x102x25 UB	35,041.080
305x102x28 UB	4,778.659
305x102x33 UB	107,547.066
406x140x39 UB	50,628.006
406x140x46 UB	19,793.671
457x152x52 UB	62,028.158
457x152x60 UB	21,787.200
356x127x39 UB	5,735.480
457x152x67 UB	4,500.872
838x292x176 UB	8,947.277

According to Table 2, the second highest EC element is external walls including curtain wall, external windows and doors. The external wall is a cavity wall comprising brick and blockwork. Aluminum doors, windows and glazing curtain walls are also included in this element. Due to the high EC of glazing and aluminium, the second highest carbon hotspot element of the building is external wall including external doors and windows.

For the purpose of comparison between embodied carbon of an office building and an apartment building in the UK, a similar type case study was used. The previous case study, by Victoria *et al*. (2015), examined an office building located in the UK under the same system boundary of cradle to gate. Although both studies have been carried using the same system boundary, the hierarchy of the carbon hotspots vary from building to building (see Table 4). This aligns with previous study in this area. It was highlighted in RICS (2014) that carbon intensive elements and their hierarchy may vary from one project to the other and from one building to the other due to heterogeneity of projects. According to the comparison between apartment building and office building "frame" was identified as the highest EC building element. For both projects, the "frame" consists of steel and concrete, which are carbon hotspots. The second highest EC element is external wall (including Curtain wall, external doors and windows) in an apartment building and substructure in the office building. The eight-storey office building has a GIFA of 11,320 m^2 with a basement. The basement consists of concrete and steel, which gives the high EC. The third highest EC element was upper floors in both buildings. While the least EC building element was internal wall and partition in the apartment building and roof in the office building. The variance in the carbon hotspots is mainly due to the different types of materials used in the apartment building and office building. For example, the apartment building has a pitched roof with an interlocking concrete roof tiling while the office building has a flat roof. However, considering both the office building and the apartment building, EC $KgCO_2$ per m^2 is higher in the apartment building than in the office building, mainly due to the building footprint of the apartment building being greater than that of the office building.

Table 4: Comparison of EC between Apartment Building and Office Buildings

Building Element	Apartment Building EC per GIFA ($KgCO_2/m^2$)-current study	Office Building EC per GIFA ($KgCO_2/m^2$)-Victoria et al. (2015)
Substructure	631.56	179.9
Frame	1,031.75	203.9
Upper Floors	672.55	97.5
Roof	185.08	16.4
External Walls including (Curtain wall, external doors and windows)	816.36	27.3
Internal Walls & Partitions	35.55	34.1
Internal Finishes Including Floor Wall and Ceiling Finishes	412.46	36.3

5. CONCLUSIONS

The research findings identified that the highest EC element in the case study apartment building is frame, due to high usage of steel and concrete. The lowest EC element was identified as internal walls and partitions, constructed using Gyproc Gypwall. Gyproc Gypwall emits less carbon. When comparing apartment building and office building, order of carbon significant elements is different. However, it is evident that when high amount of steel and concrete is used in any element, it increases the EC. However, the apartment building GIFA is lower than that of the office building, $KgCO_2/m^2$ of element in the apartment building is higher than that of the office building. The research findings highlighted the building elements that has high carbon reduction potential over the others that need more focus during the design development. The hierarchy of carbon significance of elements varies between different types of buildings with similar design features due to the difference in their specifications. This displays the complexity of achieving carbon optimum design solutions. In order to reduce carbon, careful selection of building materials and optimum design solutions is recommended. This is because carbon reduction potential can be maximised if the building envelope uses low carbon intensive materials other than steel and/or concrete, which are considered as carbon hotspots.

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ENABLING ZERO WASTE CONCEPT IN THE CONSTRUCTION INDUSTRY: A LITERATURE REVIEW

K.L.A.K.T. Liyanage*, K.G.A.S. Waidyasekara and Harshini Mallawaarachchi

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

The construction industry is one of the leading economic players in any region. However, the continuous construction and demolition activities have resulted in the generation of Construction and Demolition (C&D) waste. C&D waste management in the construction industry is still at an adolescent stage where effective reduction of C&D waste is considered as a challenging issue confronted by many economies in the world. Improper waste management has led to several issues related to environmental, economic, and social over the past years. Thus, C&D waste management is considered as a persuasive issue to be addressed. The "Zero Waste" concept has emerged as a solution to eliminate the C&D waste, which eradicates waste at the source and throughout the period of the construction activity. Many researchers have mentioned that efficient material management or waste minimisation plan is an essential process in zero waste. In this process, it is pertinent to consider the potential of which materials may generate less waste, re-useable, or recyclable, i.e., diverting materials from disposal to reuse or recycling during the construction. However, limited studies are available on zero waste management in construction industry. Therefore, this paper aims to review the importance of zero waste concept to the construction industry by critically reviewing the secondary data on waste management studies conducted in the construction industry. The paper further discusses the types of C&D waste, impacts of C&D waste, origins and causes of waste, the zero-waste concept, and the importance and its application in the construction industry. Strategies, enablers, and barriers to implementing zero waste are discussed, and finally, a conceptual framework is developed to achieve Zero Waste in the construction industry.

Keywords: *Construction and Demolition (C&D) Waste; Construction Industry; Enablers; Zero Waste.*

1. INTRODUCTION

Any material which is a by-product of human and industrial activity that has no residual value is defined as waste (Teo & Loosemore, 2001). The construction industry is considered as a main field, in which the rapid development has resulted in a massive increase of construction and demolition waste causing a significant burden to the environment (Banias et al., 2010). In construction waste, solid waste generated during new construction, renovation, and demolition of structures are identified as Construction and Demolition (C&D) waste (Wang et al., 2010). Esin and Cosgun (2007) identified that solid construction waste is comprised of asbestos, heavy metals, persistent organic compounds, and Volatile Organic Compounds (VOCs) that end up in landfills resulting environmental pollution. According to Wang et al. (2008), cement, timber, brick, concrete, aluminium, tile, and steel are the main types of construction waste materials, and C&D waste accounts for 10-30% of solid wastes at many landfills globally (Wang et al., 2010). Mhaske et al. (2017) mentioned that C&D waste contributes negative impacts on cost, time, environment, and productivity of a country, while Osmani et al. (2008) emphasised on a compelling need to reduce waste in all stages of construction by considering the long-term impacts.

Li et al. (2015) found that 33% of the waste materials are produced due to designer failures, and construction waste generation can be reduced during designing and construction by dimension coordination, using prefabricated components, employing standard dimensions and units, detail designing and avoiding design

*Corresponding Author: E-mail – kushiliyanage23@gmail.com

modifications. As per Wang et al. (2015), to reduce the adverse effect of construction waste on human health and sustainable development, a 3R principle (Reduce, Reuse, and Recycle) is used to manage the construction waste. Moreover, Osmani (2012) mentioned that the involvement and commitment of the stakeholders to reduce waste generation at source and efficient waste management strategies could lead the industry to achieve zero waste targets.

Zero waste is a whole system approach that focuses on the elimination of waste at source and during all points of the supply chain (Curran & Williams, 2012). Zero waste concept motivates optimum recycling and resource recovery, sustainable production and consumption, and restricts mass incineration and landfilling (Zaman, 2015). According to Connett (2006), the zero waste concept binds community and industry together, and hence it is certain that zero waste is a precise solution for the C&D waste management in the construction industry. Thus, this paper presents the key literature findings on the importance of zero waste concept to the construction industry, as a part of a research study in investigating the adoptability of zero waste concept to the Sri Lankan construction industry.

2. RESEARCH METHOD

As mentioned by Uyangoda (2010), a literature review is a critical assessment by the researcher on the existing body of knowledge of the theme or problem under investigation. It enables the researcher to identify essential gaps in the existing knowledge with evidence. Thus, as in any research work, conducting a systematic literature review enriches and reinforces the research process initially. Therefore, findings of comprehensive literature review presented the consequences of C&D waste in the construction industry, origin, causes of waste generation, zero waste concept and its importance to the construction industry, and enablers to implementing zero waste in the construction industry. Literature evidence was collected by referring journal articles, books, published and unpublished bibliographies, conference proceedings, industry reports, and documents that are specifically related to the construction industry, C&D waste, C&D waste management procedures, and zero waste. The literature survey was facilitated by the use of key terms such as construction and demolition waste, zero waste, enablers, and construction industry.

3. CONSTRUCTION AND DEMOLITION OF (C&D) WASTE IN THE CONSTRUCTION INDUSTRY

In most countries, C&D waste may count for a bigger portion of solid waste generation (Elgizawy et al., 2016). Hence, the construction industry is under pressure as to reduce the sizable quantities of construction waste generated during construction operations (Banihashemi et al., 2018). Although researchers have paid attention to the effective and efficient C&D waste management since the 1980s, C&D waste management is still at an adolescent stage (Hao et al., 2007).

Effective C&D waste management is a challenging issue for many countries, as they make an adverse impact on the environment (Wang et al., 2010). C&D waste can be defined as the waste generated through new construction, renovation, and demolition of buildings and structures (Kofoworola & Gheewala, 2009). According to Wang et al. (2014), C&D waste means the waste of valuable natural resources and disposal of those C&D waste to landfills leads to the scarcity in the land resource. Starting from the raw material extraction up to the demolition and waste disposal, massive quantities of waste generates from the construction industry, and the heavy use of raw materials for the construction industry has resulted in unsustainability in the industry (Elgizawy et al., 2016). Osmani et al. (2008) stated that a considerable amount of waste generates, starting from the pre-construction stage up to the completion of the construction, and according to Kofoworola and Gheewala (2009), the landfill is the favoured method for C&D waste disposal.

3.1. TYPES OF C&D WASTE

In a construction project, design and construction stages are significant as they are inter-related, and systematic waste management in one stage makes a direct impact over the next stage (Ding et al., 2018). The C&D waste composition differs according to the construction technique, building type, and country (Elgizawy et al., 2016). The authors have identified some major waste streams in construction projects such as wood, concrete, masonry, metal ferrous, metal non-ferrous, plastic, glass, insulation materials, gypsum boards, ceramic tiles, paper and cardboard, marble, and granite. As per Wang et al. (2008), construction activities generate waste types such as sludge, soil, timber and steel, from which, 95% can be recycled while remaining 5% is unrecyclable. Moreover, Hao et al. (2007) have explained that C&D waste is divided into materials, machinery, energy, and labour. According to Kofoworola and Gheewala (2009), a sizable proportion of the generated C&D waste consist of paper and plastic waste from the usage of packaging materials, formwork, and wood waste from scaffoldings. Further, Wang et al. (2008) disclose that concrete waste generation is higher in C&D waste, i.e., approximately 80%- 90%, due to the concrete demolition, plastering flow, excess ordering, and template leakage. The authors have also explained that block wastage happens due to the damages and cutover, whereas timber and brittle material wastage generates due to cutover and transportation issues. Before recycling of C&D waste, the waste generator should perform waste sorting (Wahi et al., 2016). According to Jaillon et al. (2009), C&D waste is a mixture of inert and non-inert materials, and out of the C&D waste, 70% of the construction waste is from the inert materials that can be reused for reclamation and earth-filling works. The authors have also stated that, from the C&D waste, non-inert waste account for 15% - 18% and they are either recycled or disposed to landfills. Out of the generated C&D waste, a certain percentage of waste is reduced and recycled while the remaining C&D waste is incinerated or sent into landfills, as presented in Table 1.

Table 1: C&D Waste Generation and Management in Various Countries

Country	**Waste generation**	**Waste Management**		**Source of Reference**		
	C&D waste (MT)	% Reduced/ recycled	% Incinerated/ land filled	(Jaillon et al., 2009)	(Symonds Group Limited, 1999)	(Franklin Associate, 1998)
Germany	59	17	83	√		
UK	30	45	55	√		
France	24	15	85	√		
Italy	20	9	91	√		
Spain	13	<5	>95	√		
Netherlands	11	90	10	√		
Belgium	7	87	13	√		
Austria	5	41	59	√		
Portugal	3	<5	>95	√		
Denmark	3	81	19	√		
Greece	2	<5	>95	√		
Sweden	2	21	79	√		
Finland	1	45	55	√		
Ireland	1	<5	>95	√		
Luxemburg	0	n/a	n/a	√		
Europe-15	180	28	72		√	
US in 1996	136	30	70			√
Hong Kong in 1999	13.55	79	21	√		
Hong Kong in 2005	21.45	89	11	√		
Singapore in 1999	0.41	70	30	√		
Singapore in 2005	0.49	94	6	√		

3.2. *ORIGINS OF WASTE AND CAUSES FOR WASTE GENERATION*

As per Osmani (2012), C&D waste generates due to the design changes, poor communication between design and construction team, extended project duration, and lack of design information. Further, Jaillon et al. (2009) stated that design and requirement changes of clients generate vast amounts of waste. According to Kofoworola and Gheewala (2009), C&D waste generates due to contractor's lack of interest, lack of knowledge in the designing stage, use of poor-quality products, and poor material handling. Furthermore, the authors have identified causes for concrete waste creation as, dimension deviation in structural elements and ordering of surplus of concrete to carry out the work. Moreover, the authors explained that material delivery issues and poor handling of materials cause brick and block waste and tile waste.

Insufficient environmental awareness and structural selection, lack of management skills, lack of training to manage waste, and the use of outdated technology for construction are the reasons for the generation of C&D waste (Wang et al., 2008), and these authors highlight that landfilling is the method used by the contractors to dump C&D waste. Magalhaes et al. (2017) explained that construction planning and designing decisions also lead to the C&D waste generation. Table 2 presents a review of the C&D waste origins.

Table 2: Review of C&D Waste Origins

Origins of waste	**Osmani et al. (2008)**	**Gavilan and Bernold (1994)**	**Osmani et al. (2006)**	**Formoso et al. (1999)**	**Begum et al. (2006)**	**Poon et al. (2004)**	**Li et al. (2015)**	**Osmani (2012)**	**Kulatunga et al., (2006)**
Contractual issues	√					√			
Design issues	√	√	√	√	√		√	√	√
Procurement issues	√	√		√				√	√
Transportation issues	√			√					√
On-site management and planning issues	√				√	√	√	√	
Material storage issues	√								
Material handling issues	√	√							√
Site operation issues	√	√	√				√	√	
Residual issues	√	√			√	√			
Other issues (Weather, Vandalism)	√			√					√

3.3. IMPACTS OF C&D WASTE AND SOLUTIONS FOR PREVENTION

Sapuay (2016) states that the improper management of C&D waste leads to adverse environmental impacts and health issues of humans. The author further indicates that although the development takes place in the society, waste issues can lead to an environmental catastrophe. The current practice of C&D waste dumping in landfills results in environmental issues and natural resource depletion (Elgizawyet al., 2016). Similarly, Wang et al. (2010) specified, in the current global context, C&D waste creates numerous environmental issues, and as per Coelho and Brito (2012), C&D waste damage the ecological environment, consume the land resource, and leads to soil and water pollution. Correct management of C&D waste reduce the adverse environmental impacts, undesirable landfill site creation, and health risks related to construction waste (Lingard et al., 2000).According to Sapuay (2016), construction waste is heavy, bulky, and occasionally, toxic. Magalhaes et al. (2017) have pointed out that designing strategies should focus on the environmental impacts of the construction stages. For sustainable construction activities, policies and regulations are introduced by governments to reduce the negative impacts of C&D waste (Oluwole & Olaniran, 2013). Furthermore, Elgizawy et al. (2016) reports, once the building is demolished, waste get ended up in landfills, and this creates the need to consider alternative methods for waste recycling. The authors further explained that a recycling process and profitability aspects should be available to make a sustainable environment, where recycling products of C&D waste are provided with a good market. The government involvement is necessary to provide incentives and create new regulations. As stated by Zaman (2015), to address the critical waste issue in the society, zero waste is an idealistic concept, which is an ambitious goal to handle waste.

4. ZERO WASTE CONCEPT

Zero Waste is defined as the 'redesigning of resources to reduce the harmful impacts to the environment through the emissions and to minimise resource wastage through a whole system approach' (Curran &

Williams, 2012). Critical innovations have been taking place in the development history of waste management (Zaman & Lehmann, 2011). Figure 1 illustrates the historical development of waste management.

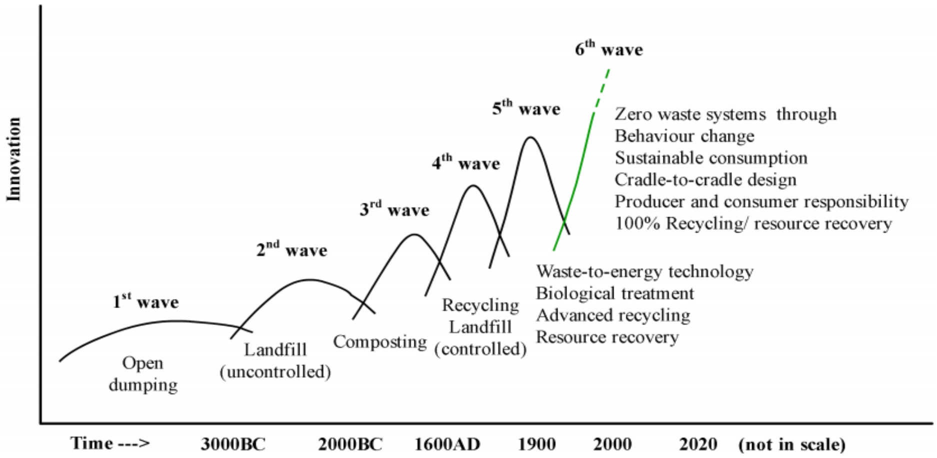

Figure 1: Historical development of waste management

Source: Zaman and Lehmann (2011)

According to Curran and Williams (2012), Zero waste concept is a unifying concept for a range of measures aimed at eliminating waste and challenging old ways of thinking. In a single framework, zero waste includes producer responsibility, eco-design, waste reduction, reuse, and recycle (Murray, 2002). Zaman (2014) defines zero waste management as the combination of waste management philosophies and integrated design. Moreover, Curran and Williams (2012) mentioned that zero waste concept could be implemented by eliminating waste at the source and throughout the supply chain, and encouraging waste diversion from incineration and landfills.

4.1. THE IMPORTANCE OF ZERO WASTE AND ITS APPLICATION TO THE CONSTRUCTION INDUSTRY

In the recent years, waste minimisation in the construction industry has drawn attention with the understanding of the waste minimisation benefits, cost-saving benefits, and environmental issues due to C&D waste (Osmani, 2012). Thus, to protect the environment and to conserve the natural resources, waste management in the construction industry is needed as it helps to reduce cost and the adverse waste disposal impacts (Akinade et al., 2018).

According to Zaman (2015), none of the articles published from 1995 to 2014 has focussed on the C&D waste documentation for zero waste. The implementation of Zero waste concept helps to achieve the optimum use of natural resources and reduce environmental issues (Zaman, 2014). According to Curran and Williams (2012), with the waste elimination through zero-waste concept, pollution issues affecting the ecosystem can be sorted, and the optimum use of raw materials and the use of renewable sources will bring the sustainability in the construction industry. Osmani (2012) reports that zero waste achievement is a highly challenging target for the construction industry. The author has further elaborated, in order to bring the construction industry closer to the Zero waste, waste reduction at source and material, and component reuse and recycle can be performed. When the construction industry focuses on waste minimisation, construction material flows through a closed loop system to preserve natural resources and to reduce waste landfilling (Akinade et al., 2018). As stated by Kofoworola and Gheewala (2009), reduce, reuse, and recovery of construction waste helps to realise employment opportunities and cost savings. The authors have further explained that environmental protection and improvement in the quality of life is achievable via C&D waste management.

4.2. STRATEGIES TO ACHIEVE ZERO WASTE IN THE CONSTRUCTION INDUSTRY

For the C&D waste management in the construction industry, 3R (Reduce, Reuse, Recycle) concept is being practised (Nitivattananon and Borongan, 2007; Wang, 2015). According to Yuan et al. (2011), the 3R concept is comprised of waste management strategies to manage C&D waste. Tam and Tam (2006) have proposed strategies such aswaste reduction at source, reusing and recycling of waste, and landfilling for C&D waste management. Moreover, Baldwin et al. (2009) indicate that Waste Minimisation Design (WMD) is a crucialstrategy for effective C&D waste management, while Bossink and Brouwers (1996) propose to manage C&D wastethrough strategies such aswaste prevention at the site and to consider environmental impacts from the designing stage. Client awareness, adhering to building regulations, and checking client demand can be other useful schemes in the construction industry (Pitt, Tucker and Riley, 2009).

According to Akinade et al. (2016), Building Information Modelling (BIM) tools can be applied along with platforms such as Revit, Micro station, Archi CAD, and Teklato manage C&D waste. Further, Ajayi et al. (2017) have stated that C&D waste can be managed through the use of minimisation and prevention strategies. Moreover, Ling and Nguyen (2013) have identified that training and supervision, management of subcontractors and workforce, material handling and control, procurement, communication, and documentation promotes C&D waste management. According to Curran and Williams (2012), to implement zero waste in the construction industry, strategies that can be followed are elaborated in Figure 2 along with the external influences and constraints. Out of the identified strategies, the authors have selected Eco design, Industrial Symbiosis, Closed loop supply chain management, Innovative technology, Product stewardship, Life cycle assessment, and Environmental Management System (EMS) as leading strategies to implement the zero waste concept.

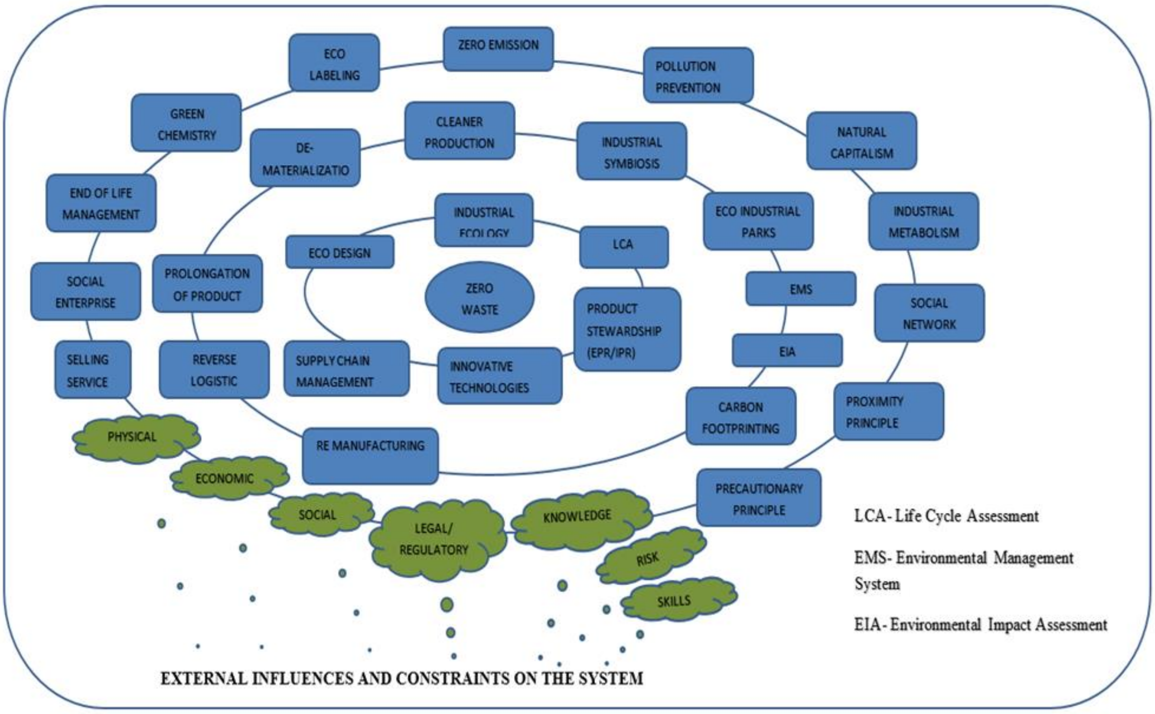

Figure 2: Zero Waste System to Achieve Zero Waste

Source: Curran and Williams (2012)

4.3. *ENABLERS TO ACHIEVE ZERO WASTE IN THE CONSTRUCTION INDUSTRY*

Appreciating the current possibilities or enablers in the construction industry is important to implement the zero waste concept effectively. According to the key literature reviewed, various enablers can be encountered. Legislation and policy, awareness and understanding, manufacture of construction products, designing and operating buildings, business, recovery of materials and products, and economics were identified as some enablers in the construction industry for waste management. Similarly, Zaman (2013) explained that social, economic, and environmental enablers could facilitate waste management in the construction industry. Further to authors, personal behaviour, local waste management practice, and consumption and generation of waste can be identified as the critical social enablers, while the resource value of waste, economic benefit from waste treatment facilities, and landfill tax are the economic enablers. As Zaman (2013) further elaborated, main enablers such as global climate change, the environmental movement, and awareness can also assist to manage C&D waste. Osmani (2011) have also identified that environmental, legislative, economic, and business enablers can reduce the waste in construction industry. Geo-administrative, socio-cultural, management, economic, environmental, organisational, and policy are the additional enablers identified for the implementation of zero waste concept (Zaman, 2014).

However, several gaps can be existed in the current procedures that need to be enhanced for the effective implementation of zero waste concepts. The barriers encountered in research projects in key literature are described in section 4.4.

4.4. *BARRIERS TO ACHIEVE ZERO WASTE IN THE CONSTRUCTION INDUSTRY*

Zou et al. (2013) discussed some barriers to manage C&D waste; i.e., lack of knowledge about what can be recycled or recycling opportunities, contamination of recyclables due to lack of separation or lack of space for separation, absence of markets for the recycled materials, technological barriers in terms of conversion of waste materials to useful ends, cost of recycling processes making products more expensive than that from virgin materials, and failure to incorporate design for deconstruction into the building process. Besides, alternatives to recycling are less costly; i.e., landfill gate prices are too low, the government policy is not driving recycling, lack of confidence in recycled materials, lack of communication and industry infrastructure, a dearth of knowledge across industry, and low value/low volume products being landfilled rather than stored for recycling. Further, Guerrero et al. (2017) identified obstacles such as lack of time to develop plans for waste reduction, deficiency of environmental regulations, and lack of available information regarding the requirements of environmental norms.

Accordingly, various strategies, enablers and barriers for implementing zero waste concept in construction industry were identified by reviewing key literature. The key findings were proposed for the next step of the research which is presented subsequently.

5. CONCEPTUAL FRAMEWORK

The major findings derived through key literature are visualised in the developed framework. The major types of C&D waste, causes of waste generation, its impact and most importantly, the strategies, enablers and barriers of implementing zero waste concept were highlighted in the framework. According to the comprehensive literature findings, major types of C&D waste may include cement, timber, brick, concrete, aluminium, tile, steel, plastic, polythene, paper, and cardboard. Figure 3 presents the conceptual framework developed as the main implication of this research paper.

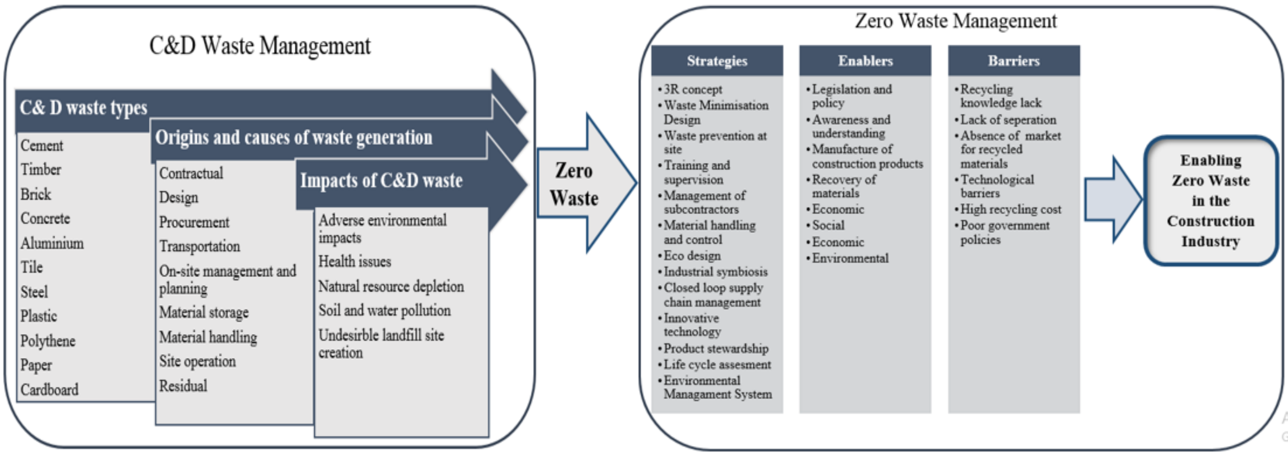

Figure 3: Conceptual Framework for Enabling Zero Waste in Construction

6. CONCLUSIONS

The construction industry, being one of the major economic contributors to the construction activities, generates a considerable amount of C&D waste, which ultimately ends up in the landfills. Therefore, to eliminate the C&D waste, this paper focused on the importance of the zero waste concept to the construction industry and the enablers to implementing zero waste in this industry. The paper discussed common types of C&D waste and the causes for originating waste in construction projects. Adverse environmental impacts, health issues, natural resource depletion, and pollutions in soil and water were identified as some negative impacts of improper C&D waste management. The zero waste concept was identified as a whole system approach to manage issues related with C&D, within which, elimination of waste takes place. Suitable strategies, enablers, and barriers to implementing zero waste in the construction industry were identified, and finally, a conceptual framework was developed to enable zero waste concept in this trade. Thus, this paper motivates future research on the application of zero waste concept to the construction industry.

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ENVIRONMENTAL SUSTAINABILITY ASSESSMENT OF FACILITIES MANAGEMENT: A CASE OF APPAREL INDUSTRY IN SRI LANKA

Nimesha Jayasena and Harshini Mallawaarachchi*

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

With the adaptation of businesses to sustainable approaches, facility manager's role has been expanded to be responsible for the sustainable performance of a building. Specially, escalating changes in the built environment has initiated the need of evaluating environmental sustainability (ES) of building facilities. Specially, apparel industry shows a significant impact to the environment, thus, it highlights the need of having a way to evaluate the environmental sustainability in facilities management (FM) in apparel sector. Therefore, this research was aimed to develop a model to evaluate the environmental sustainability of FM in apparel industry in Sri Lanka. By reviewing key literature, thirty-four (34) environmental sustainability indicators were identified under energy management, water management, waste management, asset management and maintenance management. Under the survey approach, pair-wise comparison through structured questionnaire was used to evaluate the identified indicators. Analytical Hierarchy Process (AHP) tool was used to derive the relative performance scores of each ES indicator and ranked. Energy management was identified as the most significant FM function related to environmental sustainability. Energy sub-metering and application of sub-meter reading on identification of significant energy consumers, availability of waste management policy and availability of environmental impact assessment for the assets were determined as top priority indicators that need to be considered to ensure the ES of FM in apparel industry. Accordingly, the identified performance scores can be used as a basis to evaluate the ES of FM functions in order to formulate the suitable strategies to instigate the environmentally sustainable FM practices in apparel industry in Sri Lanka.

Keywords:*Apparel Industry; Assessment; Environmental Sustainability; Facilities Management; Sri Lanka.*

1. INTRODUCTION

Achieving environmental, social and economic sustainability is a governing concern in any organisation. The increase of stakeholder requirements in sustainability acts as a motive force for organisations to achieve sustainability within their practices (Amran & Keat Ooi, 2014). With the adaptation of businesses to sustainable approaches, Facilities Management (FM) plays a major role in sustainable development. Especially, Facility Manager's role has been expanded to be responsible for assuring the instigation of sustainable building facilities (Elmualim et al., 2012). FM is a service, which is a combined approach in maintaining, improving and adjusting the built environment in order to create an environment that strongly supports the core business of an organisation (Barrett & Baldry, 2009). With the rapid changes in the environment, need of environmental sustainability is being a growing necessity. An integration of sustainability and FM is important because, FM is significant in the operations of an organisation (Hodges, 2005). Evaluating environmental sustainability of FM is useful to identify the areas which are needed to be improved in projects (Bebbington & Frame, 2003). Furthermore, it has been identified that apparel sector contributes in large quantity to environmental pollution (Junghans, 2011) and no standardised mechanism extent to evaluate ES in the apparel industry in Sri Lanka (Manjula et al., 2015). Therefore, there is an emerging need to evaluate the ES in FM in the apparel industry in Sri Lanka. Further, Elmualim et al. (2012) stated that the increasing importance of sustainability, wider variety of sustainability issues and drivers affecting and influencing stakeholders with different values, has initiated a requirement on sustainability assessment of

*Corresponding Author: E-mail – hmallawarachchi@gmail.com

industries. In line of thinking, this research was aimed to conduct an ES assessment of FM in apparel industry in Sri Lanka. Hence, this research was limited only to assess the ES of FM functions over the economic and social sustainability. Further, the study was further limited to the apparel industry in Sri Lanka; thus, the findings presented subsequently can be generalised to the aforesaid with confidence.

2. ENVIRONMENTAL SUSTAINABILITY OF FACILITIES MANAGEMENT

A major concern is on the implementation of sustainability initiatives in the apparel sector due to the increasing awareness on environmental impacts (Islam & Khan, 2014). FM profession can make an important contribution for the sustainability challenges in a business. Especially facility managers have a greater responsibility in ES (Nielsen et al., 2016). Among the FM related functions in buildings, energy management, water management, waste management, asset management and maintenance management functions were selected in this research to evaluate the ES. The highest frequency of availability in key literature was concerned as the key criteria for above selection (Nielsen et al., 2016; Sekula & Hodges, 2014). With the importance of evaluating the status of ES in facilities, several sustainability assessment criteria have emerged due the importance of sustainable development within a facility (Adams & Ghaly, 2006). Assessing FM will act as catalysts for the development of innovation in the performance of the service though no specific sustainability assessment model for FM has been developed (Pitt & Tucker, 2008). Hence, by referring to the key literature available on existing sustainability assessment models developed worldwide, ES indicators were encountered in order to assess the ES of FM. Accordingly; thirty-four (34) ES indicators were identified as stated in Table 1. The identified indicators were used to evaluate the ES of FM functions in apparel industry in Sri Lanka. The research methodology is described in Section 3.

3. RESEARCH METHODOLOGY

A comprehensive literature review was carried out to gather information on the concept of Sustainable FM and the ES indicators of FM. Under the survey method, a questionnaire survey was conducted to evaluate the identified indicators through pair-wise comparison. The sample consists of forty-eight (48) professionals (Response rate is 67%) in apparel industry including Assistant Managers (17%), Senior Executives (21%) and Executives (29%) in the fields of engineering, FM, sustainability and compliance. In the questionnaire, the comparison pairs were stated to mark the important FM function, ES indicators and their magnitude of importance.

3.1. ANALYTIC HIERARCHY PROCESS (AHP)

The use of AHP technique in this research can be justified related to the extent of key literature. Ehrhardt and Tullar (2008) stated that AHP technique as a multiple-criterion decision making technique is useful when the outcome of a decision has several different important aspects which cannot easily be summarised.

The questionnaire was developed for pair-wise comparison of sustainable FM functions and ES indicators. To make comparisons, a scale is required to indicate the magnitude of importance of one element over another element with respect to each criterion compared (Saaty, 2008). Further to author, the definitions and explanation of the ratio scale can be recognised. The ratio scale used in this research is presented in Table 2. Reciprocals of the above intensities of importance represent, if activity i has one of the above non-zero numbers assigned to it when compared with activity j. Then j has the reciprocal value when compared with i.

Pair-wise comparison

Comparison matrices and priority weights were developed by considering the Saaty's eigenvector procedure. A sample model of the pair-wise comparison matrix is illustrated in Table 3. Average of the ratings given by the respondents for each sustainable FM function is illustrated by W_1, W_2, W_3, W_4, W_5, W_6, W_7, W_8, W_9 and W_{10}. The reciprocals of them are given in the rest of the area in Table 3. Sum of each column is shown as S_1, S_2, S_3, S_4 and S_5.

Table 1: ES Indicators of FM

ES indicators	**References**																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Energy management		√		√	√		√															
Energy sub-metering and application of sub-meter reading on identification of significant energy consumers						√																
Usage of renewable energy sources	√																					
Applicability of energy audit results																				√		
Availability of referred / standards for energy efficiency	√																					
Application of energy efficiency targets																				√		
Application of advance technologies over energy management	√																					
Water management		√		√	√																	
Following efficient water fitting standards																					√	
Conducting water audit and application of audit results																					√	
Availability of as-built drawings of water distribution system and maintenance plan								√														
Availability of a baseline for water consumption																	√					
Availability of water sub-metering and data evaluations																	√					
Usage of sustainable water resources														√								
Availability of water reusing and recycling techniques																	√					
Waste management		√		√	√		√															
Availability of waste management policy			√																			
Properly identified the end disposal methods of all categories of waste generated																				√		
Life cycle analysis process availability																		√				
Availability of a green purchasing policy			√																			
Conducting waste audits											√											
Applications of reusing waste	√																					
Applications of waste recycling	√																					
Asset management		√		√	√																	
Availability of environmental impact assessment for the assets																		√				
Availability of green purchasing policy										√												
Availability of supply chain survey before purchasing										√												
Availability and application of performance monitoring system and maintenance plan of assets																√						
Application of proper GHG emissions management process																√						

Checking the environmental legal comply of each asset													√									
Extent of green building concept applications									√													
Maintenance management	√		√			√																
Availability of facility maintenance and renovations policy											√											
Materials handling and packaging sustainable measures availability	√																					
Application of proper greenhouse gas emissions management process												√										
Availability of preventive and predictive maintenance management practices								√														
Application of chemical management concept over maintenance activities												√										
Job related training on environment sustainability aspects for maintenance staff																						√
Following international standards in maintenance																			√			

References: 1. United States Green Building Council – USGBC (2017); 2. Nielsen *et al*. (2016); 3. Parekh et al. (2014); 4. Sekula and Hodges (2014); 5. Elmualim *et al*. (2012); 6. Wang et al. (2012); 7. Junghans (2011); 8. Mateus (2011); 9. Jasiulewicz-Kaczmarek and Drozyner (2011); 10. Meehan and Bryde (2011); 11. Smyth *et al*. (2010); 12. Ilangkumaran and Kumanan (2009); 13. Hertwich and Peters (2009); 14. Liu *et al*. (2008); 15. Morrow and Rondinelli (2002); 16. Hammond *et al*. (1995); 17. Grant (2006); 18. Seadon (2010); 19. Zutshi and Sohal (2004); 20. Bunse *et al*. (2011); 21. Randolph and Troy (2008); 22. Perron *et al*. (2006)

Normalised comparison

Normalising the entries was done by dividing the entry by the sum of each column in pair-wise comparison matrices. Performance score was generated by dividing the row sum from the total sum. Table 4 represents the normalised comparison matrix for sustainable FM functions. X_1, X_2, X_3, X_4 and X_5 indicate the sum of each row after normalising. X represents the total sum of the sum column in Table 4.

Consistency calculation

A measure of consistency is the Consistency Index (CI). The Consistency Ratio (CR), CR = CI/RI was derived using a Randomized Index (RI) and the average CI for randomly filled matrices (Goepel, 2013). Steps 1, 2 and 3 of consistency calculation which were used in this research are described accordingly.

Step 1: Entries in the pair-wise comparison matrix were multiplied by the performance score to obtain the eigenvector. Z is a new vector obtained through the addition of each row. Table 5 illustrates the model calculation model which was developed in this research for the consistency calculations.

Table 2: Ratio Scale

1	2	3	4	5	6	7	8	9
Equal Importance	Weak or Slight	Moderate Importance	Moderate plus	Strong importance	Strong plus	Very strong/ demonstrated importance	Very, very strong	Extreme importance

Table 3: The Sample Model of Pair-Wise Comparison Matrix

Sustainable FM functions	A	B	C	D	E
A- Energy management	1	$\mathbf{W_1}$	$\mathbf{W_2}$	$\mathbf{W_3}$	$\mathbf{W_4}$
B- Water management	$1/W_1$	1	$\mathbf{W_5}$	$\mathbf{W_6}$	$\mathbf{W_7}$
C- Waste management	$1/W_2$	$1/W_5$	1	$\mathbf{W_8}$	$\mathbf{W_9}$
D- Asset management	$1/W_3$	$1/W_6$	$1/W_8$	1	$\mathbf{W_{10}}$
E- Maintenance management	$1/W_4$	$1/W_7$	$1/W_9$	$1/W_{10}$	1
Sum	S_1	S_2	S_3	S_4	S_5

Table 4: The Sample Model of Normalised Comparison Matrix

Sustainable FM functions	A	B	C	D	E	Sum	Performance score
A-Energy management	$\frac{1}{S1}$	$\frac{W1}{S2}$	$\frac{W2}{S3}$	$\frac{W3}{S4}$	$\frac{W4}{S5}$	X1	X1/X = Y1
B-Water management	$\frac{1/W1}{S1}$	$\frac{1}{S2}$	$\frac{W5}{S3}$	$\frac{W6}{S4}$	$\frac{W7}{S5}$	X2	X2 /X = Y2
C-Waste management	$\frac{1/W2}{S1}$	$\frac{1/W5}{S2}$	$\frac{1}{S3}$	$\frac{W8}{S4}$	$\frac{W9}{S5}$	X3	X3 /X = Y3
D-Asset management	$\frac{1/W3}{S1}$	$\frac{1/W6}{S2}$	$\frac{1/W8}{S3}$	$\frac{1}{S4}$	$\frac{W10}{S5}$	X4	X4 /X = Y4
E-Maintenance management	$\frac{1/W4}{S1}$	$\frac{1/W7}{S2}$	$\frac{1/W9}{S3}$	$\frac{1/W10}{S4}$	$\frac{1}{S5}$	X5	X5 /X = Y5
						X	

Table 5: The Consistency Calculation Model

Sustainable FM functions	A	B	C	D	E	Sum	Performance score
A- Energy management	$1*Y_1$	W_1*Y_2	W_2*Y_3	W_3*Y_4	W_4*Y_5	Z_1	$Z_1/ Y_1=a_1$
B- Water management	$1/W_1*Y_1$	$1*Y_2$	W_5*Y_3	W_6*Y_4	W_7*Y_5	Z_2	$Z_2/ Y_2=a_2$

Sustainable FM functions	A	B	C	D	E	Sum	Performance score
C- Waste management	$1/W_2*Y_1$	$1/W_5*Y_2$	$1*Y_3$	W_8*Y_4	W_9*Y_5	Z_3	$Z_3/ Y_3=a_3$
D- Asset management	$1/W_3*Y_1$	$1/W_6*Y_2$	$1/W_8*Y_3$	$1*Y_4$	$W_{10}*Y_5$	Z_4	$Z_4/ Y_4=a_4$
E- Maintenance management	$1/W_4*Y_1$	$1/W_7*Y_2$	$1/W_9*Y_3$	$1/W_{10}*Y_4$	$1*Y_5$	Z_5	$Z_5/ Y_5=a_5$

Step 2: λ_{max} was calculated using the equation presented below. λ max is the average value of the column sum. The equation used is presented below.

$$\lambda_{max} = \frac{a1+ a2+ a3+ a4+ a5}{5} \qquad \text{Eq. (01)}$$

Where, a= sum.

Step 3: Consistency Index (CI) and Consistency Ratio (CR) were calculated as per the Eqs. (02) and (03) respectively.

$$CI= \frac{\lambda_{max} - n}{(n-1)} \qquad \text{Eq. (02)}$$

$$CR = \frac{CI}{RI} \qquad \text{Eq. (03)}$$

Further, Saaty's rule of thumb can be used to accept only judgment matrices with CR< 0.1 (Deng et al., 2014). The random consistency index used in this research is presented in Table 6.

Table 6: Random Consistency Index

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Source: Saaty (2008)

Accordingly, the performance score of sustainable FM functions and related ES indicators were calculated and ranked as described in Section 4.

4. DATA ANALYSIS AND FINDINGS

The identified ES indicators of energy management, water management, waste management, asset management and maintenance management functions were analysed using the AHP technique. As the key findings derived through data analysis, FM functions and related ES indicators were ranked based on the relative performance scores calculated.

4.1. ENVIRONMENT SUSTAINABILITY ASSESSMENT OF FM FUNCTIONS

The FM functions of energy management, water management, waste management, asset management and maintenance management and related ES indicators were evaluated and ranked based on the relative performance score calculated. The rankings of FM functions and ES indicators are presented in Table 7. According to the analysis, the highest relative performance score of 0.4912 was achieved by energy management function where second, third and fourth places were achieved respectively by water management (performance score= 0.2139), maintenance management (performance score= 0.1198) and waste management (performance score= 0.0964) respectively. The least importance function of asset management received the relative performance score of 0.0785. It demonstrates that energy management is approximately two times relatively important than water management and four times relatively important than maintenance management. Therefore, energy management can be recognised as the most important FM function in ES.

Table 7: Ranking of ES indicators

ES indicators	Performance score	Rank
Energy management	**0.4912**	**1**
Energy sub-metering and application of sub-meter reading on identification of significant energy consumers	0.2360	1
Usage of renewable energy sources	0.2209	2
Applicability of energy audit results	0.1714	3
Application of energy efficiency targets	0.1704	4
Availability of referred codes and standards for energy efficiency	0.1216	5
Application of advanced technologies over energy management	0.0796	6
Water management	**0.2139**	**2**
Conducting water audit and application of audit results	0.2179	1
Following efficient water fitting standards	0.1627	2
Usage of sustainable water resources	0.1377	3
Availability of a baseline for water consumption	0.1305	4
Availability of water sub-metering and data evaluations	0.1296	5
Availability of as-built drawings of water distribution system and maintenance plan	0.1276	6
Availability of water reusing and recycling techniques	0.0940	**7**
Maintenance management	**0.1198**	**3**
Availability of facility maintenance and renovations policy	0.2084	1
Availability of preventive & predictive maintenance management practices	0.2044	2
Materials handling and packaging sustainable measures availability	0.1496	3
Application of proper greenhouse gas emissions management process	0.1491	4
Job related training on ES aspects for maintenance staff	0.1203	5
Application of chemical management concept over maintenance activities	0.0977	6
Following international standards in maintenance	0.0705	7
Waste management	**0.0964**	**4**
Availability of waste management policy	0.2302	1
Life cycle analysis process availability	0.1837	2
Proper identification of the end disposal methods of all categories of waste	0.1705	3
Availability of a green purchasing policy	0.1524	4
Applications of reusing waste	0.1027	5
Conducting waste audits	0.0976	6
Applications of waste recycling	0.0630	7
Asset management	**0.0785**	**5**
Availability of environmental impact assessment for the assets	0.2597	1
Availability of green purchasing policy	0.1886	2
Availability and application of performance monitoring system and maintenance plan of assets	0.1313	3
Availability of supply chain survey before purchasing	0.1120	4
Application of proper greenhouse gas emissions management process	0.1103	5
Checking the environmental legal comply of each asset	0.1023	6
Availability of green building concept applications	0.0957	7

According to the analysis, 'Energy sub-metering and application of sub-meter reading on the identification of significant energy consumers' received first ranking with the relative performance score of is 0.2360.'Usage of renewable energy sources' was identified as the second most important indicator with the performance score of 0.2209. However, it indicated that there is a slight difference between the first and second ranks. Further, the relative performance score of the third (Applicability of energy audit results) and fourth (Application of energy efficiency targets) ranks also did not show a considerable difference. It states an equal importance of the indicators. 'Availability of referred codes and standards for energy efficiency' is approximately half (1/2) of the relative weight of the rank one. The indicator of 'Application of advanced technologies over energy management' was ranked at the sixth place and approximately it was one third (1/3) of the first rank of energy management.

The relative performance scores of ES indicator in water management which were derived through AHP process are illustrated in Table 7. The highest relative performance score of 0.2179 was obtained by 'Conducting water audit and application of audit results' while, 'Following efficient water fitting standards' (performance score= 0.1627) was the second. The first ranked indicator is approximately 1.5 times greater than the thirdly ranked indicator of 'Usage of sustainable water resources' (performance score= 0.1377). According to the analysis, the fourth, fifth and sixth ranks were achieved by 'Availability of a baseline for water consumption', 'Availability of water sub-metering' and 'Data evaluations and availability of as-built drawings of water distribution system' and 'Maintenance plan' with their relative performance scores of 0.1305, 0.1296 and 0.1276 respectively. From the analysis of the relative weights, minor deviations among indicators were identified. Further, it can be identified that the professionals are more interested in applying sustainable water management practices before occurring water wastage. The ES indicators of maintenance management were ranked based on the relative performance score values calculated through AHP analysis (Table 7). 'Availability of facility maintenance and renovations policy' was ranked as the top priority indicator with the relative performance score of 0.2084. 'Availability of preventive and predictive maintenance management practices' was ranked as the second important indicator with the relative performance score of 0.2044. As recognised in analysis, a substantial difference was not found between the relative scores of first and second rankings. Thus, an equal importance of those two indicators can be observed. The third and fourth ranks which were received respectively by 'Materials handling and packaging sustainable measures availability' and 'Application of proper greenhouse gas emissions management process and monitoring the carbon footprints relevant to each maintenance activities' can also be considered as the equally important criterions because of their approximately equal relative scores. The lowest relative performance score was obtained by 'Following international standards in maintenance' with the relative performance score of 0.0705. It was approximately one third (1/3) of the first rank. From the analysis, it can be identified that the availability of maintenance related policies could affect more on the ES of maintenance management in apparel industry. The comparison of key findings with related research works in key literature is presented subsequently.

According to the analysis of ES indicators in waste management, 'Availability of waste management policy' received the top rank with its relative performance score of 0.2302. Second, third and fourth ranks were correspondingly achieved by 'Life cycle analysis process availability', 'Proper identification of the end disposal methods of all categories of waste generated' and the 'Availability of a green purchasing policy' with the respective performance score values of 0.1837, 0.1705 and 0.1524. The fifth and sixth ranks were approximately half (1/2) of the first ranked indicator. Among the ES indicators in waste management, a substantial deviation of the relative weights was not found. Moreover, it can be identified that the professionals prefer to focus on preventing waste generation rather than managing the waste generated. Based on the relative performance scores derived through the AHP process, the ES indicators of asset management were ranked as illustrated in Table 7. The highest relative performance score was obtained by 'Availability of environmental impact assessment for the assets' (performance score=0.2597). The least relative performance score was obtained by 'Availability of green building concept applications with the score value of 0.0957. The first ranked indicator was deviated by approximately three times from the least performance score. Therefore, a considerable deviation of the relative performance scores can be identified between the first and preceding ES indicators. Among the ES indicators in asset management, the assessments and policies on asset management can have a greater impact on the ES in apparel industry.

5. DISCUSSION

The findings showed the relative performance of ES indicators of selected FM functions. Accordingly, energy sub-metering and application of sub-meter reading, conducting water audit and application of audit results, availability of waste management policy, availability of environmental impact assessment for the assets and availability of facility maintenance and renovations policy were determined as top priority ES indicators among the others. According to the findings, energy management obtained a higher performance score than other functions. Junghans (2011) also stated that energy management is the heart of buildings, which states the importance of energy management. Furthermore, USGBC (2017) stated that LEED certification has an increased emphasis on energy and the associated impacts as well. When considering the performance scores of ES indicators of energy management, the highest performance score was obtained by energy sub-metering and application of sub-meter reading on identification of significant energy consumers. A similar study conducted by Wang and Xiao (2012) stated that identification of energy consumption in different zones is an important requirement for energy management. Moreover, it was found that 'conducting water audits' another top priority indicator with a high relative weight among other ES indicators of water management. It was further proven by Batchelor et al. (2003) stating that the audits could form practical recommendations in water management. By referring to the findings, availability of waste management policy which addresses ES was also recognised as a top ranking indicator. Parekh et al. (2014) mentioned that the policy could affect the total waste management procedure, which confirms the importance of such. Seadon (2010) identified the importance of ES assessment for assets. A similar outcome was derived in this research where availability of environmental impact assessment for the assets was recognised as the top priority ES indicator in asset management with the highest performance score. Ilangkumaran and Kumanan (2009) stated the importance of a maintenance policy for any facility as it plays a key role in achieving organisational goals. This research found that the availability of maintenance policy is important for assuring ES of maintenance management in apparel industry in Sri Lanka.

6. SUMMARY

With the long-term value addition for the shareholders and with the gain from sustainable development, organisations are interested in adapting with sustainable practices. Though sustainability is the integration of environmental, social and economic pillars, ES can be considered as the root of sustainable development because a healthy environment is essential. The integration of sustainability and FM is also paramount as FM is significant in the operations of an organisation. Especially, integration of ES and FM in apparel industry can also be recognised as it could contribute in large quantity to reduce the environmental impact of buildings. Since having less consideration on evaluating the ES of FM practices in apparel industry, this study stands as the best way to implement. Outcomes of this research are beneficial for the FM practitioners of the apparel industry in Sri Lanka for improving the ES. Here, a clear guidance has been provided to calculate the ES of FM in apparel industry. In addition to that, a computer-based assessment model will be developed as the next step to facilitate the industry practitioners an ease of evaluating ES of FM in apparel industry in Sri Lanka.

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EVALUATION OF MARKETING PRACTICES AND MARKETING PERFORMANCE MEASUREMENTS UNDERTAKEN BY QUANTITY SURVEYING CONSULTANCY FIRMS IN SRI LANKA

P.K. Nethmini*, K.G.A.S. Waidyasekara and D.G. Melagoda

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Marketing is now recognised as one of the important functions necessary to meet the unprecedented challenges faced by a firm. This concept can be suggested as an answer to the professional firms to sustain demand, growth, and profitability. Although marketing is the management process responsible for identifying and satisfying clients' requests, and profitably, Quantity Surveyors (QSs) still have a limited understanding of marketing and how it is implemented in the changing and challenging market conditions to enhance business growth. Hence, this research paper aims to evaluate the formalised marketing practices and marketing performance measurement systems used in Quantity Surveying Consultancy Firms (QSCFs) in Sri Lanka. After a thorough literature review of formalised marketing practices, endeavours were made to discover the realism and their importance to QSCFs in Sri Lanka through a questionnaire survey. A total of 31 responses were accounted for the analysis of 12 QSCFs in Sri Lanka. The findings revealed that the adoption of the 'marketing practices' in the Quantity Surveying (QS) business is still in its formative stage. However, the majority of respondents recognised the importance of adopting marketing activities as a business development activity. Quality service delivery, measuring customer satisfaction, and personal relationship management activities seem to be the critical marketing practices for QSCFs in Sri Lanka. At present, the majority of QSCFs pay minimum attention to measuring the performance of marketing outcomes using advance measurement indicators, but most respondents strongly agreed on the performance measurement of marketing practices will help to enhance their business success.

Keywords: *Management Process; Marketing; Performance Measurement; Quantity Surveying Consultancy Firms.*

1. INTRODUCTION

The construction industry is typically characterised by extreme competition, high risk, and low-profit margins when compared with other industries (Mochtar & Arditi, 2001). Raftery et al. (1998) described the increase of private sector involvement, vertical integration, and foreign participation in domestic constructions are the significant factors that promote the increased competition in the construction industry, which induce a high competition among Construction Consultancy Firms (CCF). Kotler and Armstrong (2008) defined marketing in professional services as "organized activities and programmes by professional services firms that are designed to retain present clients and attract new clients by sensing, serving, and satisfying their needs through the delivery of appropriate services on a paid basis in a manner consistent with credible professional goals and norms (p.225)". Eccles (1995) explained the performance measurement in the marketing field as managing and analysing marketing performance to maximise its effectiveness and to optimise its return on investments. Low et al. (2016) observed that customer satisfaction and customer loyalty are the two major indicators of marketing performance. Traditionally, professional stakeholders, i.e., Engineers, Architects, and QSS, engaged in the construction industry have ignored the importance of marketing (Jaafar et al., 2008). Hence, marketing is not viewed as a legitimate management activity in most QSCF (Ogbu, 2015). In general, CCF undertake simple marketing practices when in-house jobs are almost completed (Jaafar et al., 2008). Facing changes and challenges, including the recession and increasing competition, are hard-to-come-by projects (Low et al.,

*Corresponding Author: E-mail – kasunnethmini@yahoo.com

2016). Currently, many QSCFs have committed themselves to have several marketing plans, undertaken to enhance their business performance. Therefore, this paper attempts to evaluate the marketing practices and marketing performance of QSCFs in Sri Lanka by achieving the following three (03) objectives: (i) Review formalised marketing practices applicable to the QS business development process; (ii) Determine the extent of the importance and applicability of formalised marketing practices in QSCFs in Sri Lanka; and (iii) Evaluate QSCFs' opinions on measuring marketing performance, which is found to be the most influencing on marketing strategic decisions of QSCFs.

2. LITERATURE REVIEW

2.1. MARKETING IN CONSTRUCTION INDUSTRY

The Chartered Institute of Marketing (CIM) has defined "*Marketing is the management process responsible for identifying, anticipating, and satisfying customer requirements profitably*" (CIM, 2015, p.3). As a management function, marketing received an important position in various industries for increasing market shares, satisfying clients, building long-term relationships, ensure profitability, strengthening competitive advantages, and achieving firm performance (Naranjo *et al.,* 2011). Marketing helps construction companies to differentiate themselves from their competitors and cultivate and keep clients, and thereby create competitive advantages (Polat & Donmez, 2010). Preece *et al.* (2006) explained that rather than doing mass advertising and promotional activities, construction marketing requires long-term personal and professional contacts. Moreover, Pettinger (1998) highlighted that the loss of a single sale creates a direct financial impact on a construction company. According to Jepson and Nicholson (1972), marketing attracts an increasing attention in companies, and marketing principles have progressed in the construction industry. Yisa *et al.*(1995) observed both contractors and consultancy firms have recognized the role of marketing in the construction industry. Even today, marketing practices followed by construction companies are limited to the basic marketing philosophy (Dikmen *et al*., 2005). However, a majority of CCF operates on a small-scale basis and without a separate marketing department (Jaafar *et al.,* 2008). Authors further explained that firms marketing-related responsibilities were implemented by company directors and partners. Naranjo *et al.* (2011) described that construction companies jointly used several marketing strategies, such as market/product focus, marketing mix, social marketing, relationship marketing, customization, and pricing strategy. In addition, marketing becomes a top-management priority and most firms spend 3% to 5% of their annual turnover for marketing (Yisa *et al.,* 1995). Also, the majority of firms lack a formal marketing plan although marketing professionals are employed full-time.

2.2. MARKETING IN PROFESSIONAL SERVICE FIRMS

Young (2005) stated that the professional services industry is one of the largest and most diverse sectors of the modern economy. Maister (2007) observed that a grouping together of professionals in professional service firms to sell their services to clients more effectively than they performed individually. Kotler and Connor (1977) highlighted, "*Professional service market consists of organized activities and programs by professional services firms that are designed to retain present clients and attract new clients by sensing, serving, and satisfying their needs through delivery of appropriate services on a paid basis in a manner consistent with credible professional goals and norms*" (p.72).

2.3. QSCF AND THEIR MARKETING PRACTICES

As a recognized profession in the construction industry, QS professionals generate more value for money from scarce resources (Preece *et al.,* 2008). QSs realized benefits of client-focused marketing to increase profits, reduce uncertainty and generation of new businesses (Preece *et al.,* 2006). To maintain professionalism and profit margins, the need for formal business planning is highlighted within QSCF's (Yankah & Donald, 2015). Yankah (2015b) stated that marketing activities are important to QSCF and that deserves firms to compete with competitors. Further, Preece *et al.* (2008) seen, product branding, soliciting prospective clients and maintaining company website is the important marketing activities to the QSCF's. Yankah (2015a), analyzed 5P's of marketing management strategies on QSCF and identified 'Product' and 'Place' are important factors and 'Price', 'Promotion' and 'People' factors are moderately important to QS business development. Ogbu,

(2015) believed that People/Organizational strategies, Promotional and Educational strategies, and Price strategies were directly important to overcome market challenges in QS consultancy industry.

2.4. QS BUSINESS DEVELOPMENT PROCESS

Cannon and Hillebrandt (1990) expressed that the profit growth, increase manpower, and diversified clients are the three dimensions of QS firms' growth. According to the findings of Rodger (2010), marketing research management, marketing operations management, marketing communications management, and client–base relationship were the four-main applicable marketing management functions for a QS consultancy business development. Developing objectives, mission, and vision; identifying strengths and weaknesses; scanning and evaluating threats and opportunities, will provide a considerable advantage to be competitive among rivals within the dynamic construction environment (Hassan *et al.*, 2007).

2.5. MARKETING RESEARCH MANAGEMENT

Kotler and Armstrong (2008) defined Marketing Research (MR) as "*the systematic design, collection, analysing, and reporting of data relevant to a specific marketing situation facing a firm*" (p.95). Hassan *et al.* (2007) expressed that MR provides details for firms about new business areas, how to allocate resources, whether to expand business scope/operations, whether to enter international markets, whether to merge or combine firms together and how to avoid challenges of competitors. As depicted in literature, MR leads to QSCF growth and MR includes following key management activities:

- Business intelligence studies
- Developing a vision and mission
- Identifying an organization's external opportunities and threats
- Establishing long-term objectives
- Determining internal strengths and weaknesses
- Generating alternative strategies
- Choosing particular strategies to pursue

2.6. MARKETING OPERATION MANAGEMENT AND MARKETING COMMUNICATION MANAGEMENT

Rodger (2010) defined Marketing Operation Management (MOM) as '*the daily business of the business, which includes features of products, services, and brands'.* Preece *et al.* (2008) believed that interpersonal skills are conclusive for MOM in QSCF to conquest market challenges while providing quality service to customers is identified as the most critical activity in MOM (Low *et al.,* 2016). Authors further believed that if a satisfactory service is not delivered to the customer, the brand image within the industry may be recovered by giving compensation or making an apology. Thus, inter-industry brand image or reputation is identified as the crucial aspect of QS consultancy industry to retain old customers and attract new ones. Marketing Communication Management (MCM) involves identifying the target audience and shaping a well-coordinated promotional programme to obtain the desired audience response (Kotler & Armstrong, 2008). Advertising is of low priority in QS business development due to high cost (Preece *et al.,* 2008). As per Rodger (2010), online marketing becomes a popular marketing communication media in QS business development, and Preece *et al.* (2008) confirmed that website is a vital marketing communication method in QSCFs.

2.7. MARKETING RELATIONSHIP MANAGEMENT

Kotler and Armstrong (2008) confided that Marketing Relationship Management (MRM) is the most conclusive activity in business development and it comprises managing individual customers carefully, to maximize customer loyalty. Rodger (2010) identified three types of customers, with whom a firm may build a relationship: (i) Customers from the target market, who are the priority in the long-term, (ii) Customers from target prospect situations, who are the immediate priority for maximum specific marketing development activities and (iii) Current clients.

Keeping current customers in a satisfactory condition is identified as the most important activity in the QS business development rather than referring new clients from a competitive market (Hassan *et al.,* 2007).

2.8. *MARKETING PERFORMANCE MEASUREMENT*

O'Sullivan *et al.* (2009) described Marketing Performance Measurement (MPM) as *"the assessment of the relationship between marketing activities and business performance"* (p.844). MPM led to learning about marketing decision improvements within the firm (Clark, 1999). It demonstrates the link between marketing expeditor and actual performance of the firm (O'Sullivan & Butler, 2009). Kotler and Armstrong (2008, p.55) defined marketing expeditor as "*investment that produces a return in the form of the more profitable customer relationship.*"

According to O'Sullivan and Abela (2007), marketing investments create intermediate outcomes such as, customer thoughts, feelings, knowledge, and behaviour, which in turn influence financial performance of the firm. Authors further believed that marketing investments improve customer value and satisfaction. Marketing performance measures the effectiveness of marketing strategies followed by company (Ogbu, 2015).

2.9. *MARKETING PERFORMANCE MEASURES*

"*Effective methods of assessing marketing productivity to the business community will be a major step toward raising marketing's vitality in the firm and, more importantly, toward raising the performance of the firm itself*"(Rust *et al.*, 2004, p.76). O'Sullivan and Abela (2007) explained that the inability to demonstrate marketing effectiveness was the major challenge for marketing adoption in the firms' business development process. A company can assess marketing performance in terms of indicators such as brand awareness, and sales or market share (Gronholdt & Martensen, 2006). Mathematically, it is the net return on a marketing investment divided by the cost of the marketing investment (Kotler & Armstrong, 2008).O'Sullivan and Abela (2007) observed three (03) streams of marketing performance measures, i.e., i) Measurement of marketing productivity; (ii) Identification of metrics in-use, and (iii) Measurement of brand equity.

According to Clark (1999), there are three (03) directions of marketing performance measures: i) from financial to non-financial output measures, ii) from output to input measures, and iii) from one-dimensional to multidimensional measures. Pont and Shaw(2003)identified profit, return on investment, and returns on assets are financial output measuring factors and consider the customer satisfaction as non-financial marketing performance measure. Furthermore, O'Sullivan and Abela(2007) explored another criterion for marketing performance measurement, which isparticularly financial, non-financial, and market-based assessments (Refer to Table 1). Low *et al.* (2016); O'Sullivan and Abela (2007) and Yankah (2015a)identified eleven marketing performance measurement metrics under the above three (03) categories, which were applicable for CCF as presented in Table 1.

Table 1: Marketing Performance Measurement Indicators

Financial MPM Indicators	Non-Financial MPM Indicators	Market-Base Assessment
Cost of investments in marketing vs. benefit analysis	Customer affinity (in terms of loyalty and retention)	Number of visitors to the website
Customer acquisition cost	Decision accuracy	Market share against competitors
Wallet share (share of spending on marketing efforts)	Mindshare (brand awareness) against competitors	Number of referrals per year
	Amount of resources (human and time) used for marketing	Customer satisfaction

Sources: Low *et al.* (2016); O'Sullivan and Abela (2007); Yankah (2015a)

3. RESEARCH METHODOLOGY

A comprehensive literature survey was done initially, through books, journals, articles, and research papers to fulfil research objectives, obtained existing knowledge on the topic and to develop the questionnaire outline. The questionnaire survey was performed with the QSCFs' stakeholders to gather data on the level of importance, level of applicability of marketing management activities, the importance of marketing performance metrics, and view on measuring marketing performance with Sri Lankan QSCFs. A set of given marketing activities and marketing performance measurement indicators were analysed using weighted mean, standard deviation, and the Relative Important Index (RII). RII value was used to rank the variables and check the acceptability of the variables. The quantitative value 3 was allocated to the medium significance, and hence the variable, in which RII percentage was equal to or above 60%, was considered as an acceptable factor. RII value in between 80% -100% was considered as strongly significant, 70%-79.99% was considered as moderately significant, and RII value in between 60% - 69.99% was considered as the marginally significant factor. If two factors acquire same RII value,the one with the lower standard deviation was considered as the higher rank, since the factor with a lower standard deviation has high reliability. Convenience sampling approach was used to carry out this study. Altogether 50 questionnaires were distributed among the members of fifteen QSCF in Sri Lanka. Out of that, the overall success questionnaire response rate was 62%.

4. DATA ANALYSIS AND FINDINGS

Out of the 31 surveyed respondents, 58% were from small and medium QSCFs having less than 15 staff members. The remaining 42% of the respondents were from large QSCFs with over 15 staff members. Nearly fifty percent of the respondents were involved with management-related functions within the firm, while the remaining respondents are occupied as QSs. Designations of the respondents represent business development managers (10%), senior associates (16%), directors (26%), and senior QSs (48%). The representation by each category is given within the parenthesis. The characteristics of the respondents have enhanced the reliability of the survey results and its relevance to the QS consultancy industry in Sri Lanka.

4.1. MARKETING MANAGEMENT FUNCTIONS IN QSCF BUSINESS DEVELOPMENT PROCESS: IMPORTANT FACTORS

Table 2 illustrates the importance of activities discovered under four (04) marketing management functions of QSCFs according to their importance within each marketing management function. They are, (i) Market Research, Analysis, and Planning-MF1; (ii) Marketing Operations Management-MF2; (iii) Marketing Communications Management-MF3; and (iv) Personal Relationship Management-MF4. Finally, an overall rank is given to each activity.

Table 2: The Level of Importance of Marketing Management Activities

Code	Activity	Mean	Stranded deviation	RII	Rank	Overall rank
MF1	**Market Research, Analysis, and Planning**					
MF1.1	Vision, mission, andvalue statements	4.516	0.508	90.32%	1	5
MF1.4	SWOT analysis	4.226	0.425	84.52%	2	8
MF1.3	Target market segments and portfolio mix by priority	4.194	0.703	83.87%	3	9
MF1.2	Communications and information Packages	3.935	0.814	78.71%	4	10
MF1.6	Business intelligence study	3.839	0.735	76.77%	5	11
MF1.5	Service promotion activities	3.387	0.844	67.74%	6	16
MF2	**Marketing Operations Management**					
MF2.2	Quality service delivery	4.968	0.180	99.35%	1	1
MF2.4	Staff training	4.452	0.624	89.03%	2	7
MF2.1	Service recovery	3.806	0.749	76.13%	3	12
MF2.3	Brand image	3.742	1.125	74.84%	4	13
MF3	**Marketing Communications Management**					
MF3.2	Development and planning of information packages to target customers	3.645	0.709	72.90%	1	14
MF3.1	Internet marketing	3.645	1.018	72.90%	2	15
MF3.3	Media advertising	2.161	1.098	43.23%	3	17
MF4	**Personal Relationship Management**					
MF4.4	Client base relationship management	4.935	0.250	98.71%	1	2
MF4.1	Establishing good relationships during project execution	4.839	0.374	96.77%	2	3
MF4.3	Post-delivery client relationship interactions	4.710	0.461	94.19%	3	4
MF4.2	Two-way communication during interview presentations	4.452	0.568	89.03%	4	6

4.1.1. MANAGEMENT FUNCTION 1: MARKET RESEARCH, ANALYSIS, AND PLANNING

It is apparent in Table 2, the 'vision, mission, and value statements' (MF1.1) is crucial and mutual activity under Management Function 1. This discloses that respondents who owned or occupied in QSCFs believe that having a strong vision and mission statement for the firm is the most significant activity. This result well-matches with the literature review. According to the literature findings, vision, mission, and values were the starting points for any organisation, and these statements were the main elements of an organisation's strategic planning (David, 2011). SWOT analysis (MF1.4) can be identified as the second important activity in market research, analysis, and planning. In general, SWOT analysis assist in auditing the strengths, weaknesses, opportunities, and threats confronted by a business. The findings revealed that many QSCF now believe SWOT analysis will help to enhance their business performance. Target market segments and portfolio mix by priority-MF1.3 is identified as the third significant market research, analysing, and planning activity. This proves many firms realise the importance of providing services to current market requirements such as using new technologies and standards. Out of six (06) activities under management function 1, "service promotional activities- MF1-5" appears to be least important, as respondents felt that it would only be implemented once the firms' in-house jobs are almost completed.

4.1.2. MANAGEMENT FUNCTION 2: MARKETING OPERATIONS MANAGEMENT

According to Table 2, four (04) main activities were identified under the 'Marketing operations management function- MF2'. Majority of the respondents believe that 'Quality service delivery- MF2.2' as the most important operation management activity. Also, based on overall rank, this activity can be identified as a strong and significant activity under all four management functions. This result suggests that QS consultancy service must have an operational reality in cost saving, and not merely a marketing wish to remain competitive in the changing business world. Quality services always satisfy clients' needs and will affect the good relationship between parties during project execution. These relationships will influence future project opportunities to the firm. Staff training (MF2.4) is ranked as the second important activity under Management Function 2 and directly links to the quality of service delivery. Trained staff will ensure the high standard and ethical services to the clients. By that, firms can easily fulfil clients' requirements. Respondents considered that service recovery (MF2.1) was the next important marketing operation management activity, and commented that if they fulfil this activity suitably, it will create a tendency to return clients for their future projects. They explained that this can achieve clients' satisfaction and may require few efforts and resources for business development and marketing. Brand image acquired minimum importance under this function because many stakeholders in consultant industry believe that a brand name automatically increases through quality service delivery. Further, respondents believed that well-trained staff could efficiently deliver a quality service to their clients.

4.1.3. MANAGEMENT FUNCTION 3: MARKETING COMMUNICATION MANAGEMENT

According to Table 2, out of three activities under Management Function 3, Internet marketing (MF3.1) and Development and planning of information packages to targeted customers (MF3.2) received the same rank. As per the respondents' opinion, they are interested in internet marketing by the ways of maintaining company website and a Facebook page. Nevertheless, they do not believe that it may indeed influence generating new clients and job opportunities. As a mass and cheaper information delivery method, internet marketing delivers information about company capabilities and experiences on past projects to the clients who have no idea about the company service. A significant number of respondents from large-scale organisations stated that MF3.2 activity is applicable for large-scale projects only because it requires additional effort and manpower to develop this kind of project-specific information package. According to the collected opinions, other projects were given a general package to ensure an efficient business approach. Media advertising (MF3.3) was ranked as the least important activity from the identified activities. Addressing the entire society is not beneficial because QS consultancy is not a primary service for the society. Furthermore, respondents commented that creating effective commercials were difficult within the established ethical and financial boundaries.

4.1.4. MANAGEMENT FUNCTION 4: PERSONAL RELATIONSHIP MANAGEMENT

Personal relationship management is the fourth management function, which is more critical to QS business development than other functions. According to the literature findings, personal contacts were the main project generation source in QS consultancy firms. It is apparent in Table 2 that all respondents have given a high weight to personal relationship management activities. Client-base relationship management (MF4.4) was ranked as first in this management function. This indicates their concern about long-term relationship development, and the respondents highlighted their high effort to maintain a long-term relationship with clients. Establishing good relationships during project execution (MF4.2) was ranked as the second in this category. Project executions can be defined as the most critical phase of any project, and there is a consensus among respondents' that a good relationship during project execution will generate new project opportunities from existing clients. Further, some respondents notified that maintaining a good relationship with parallel service-providing professionals such as architects and engineers is also important to acquire new projects to the organisation since they have experienced that many clients seek suggestions from these professionals on QS consultant selection. A good relationship with parallel professional may help to receive positive suggestions about the firm in such situations. Post-delivery client relations interactions (MF4.3) and Two-way communications during interview presentations (MF4.2) were ranked as third and fourth important activities respectively, whereas a Two-way communication helps to identify clients' expectations, i.e., useful in achieving those expectations, without complications.

4.2. *APPLICABILITY OF MARKETING MANAGEMENT FUNCTIONS IN SRI LANKAN QSCFS*

The respondents were given same activities to present their views on the applicability of marketing management functions, and Figure 3 depicts the RII values of the applicability of marketing management functions and its importance. It is apparent in Figure 3, in seven (07) activities, the RII value was above 80% and was identified as strongly-practising marketing management activities in Sri Lankan QSCF. They are Quality service delivery (MF2.2), Establishing good relationships during project execution (MF4.1), Client base relationship management (MF4.4), Post-delivery client relationship interactions (MF4.3), Two-way communication during interview presentations (MF4.2),Vision, mission, and value statements (MF1.1), and Target market segments and portfolio mix by priority (MF1.3). Further, as per Figure 3, five activities which are moderately applicable (70%- 79.99%) and all other activities belong to 'marginally applicable' category since RII value is between 60% - 69.99% in the QSCF business development process.

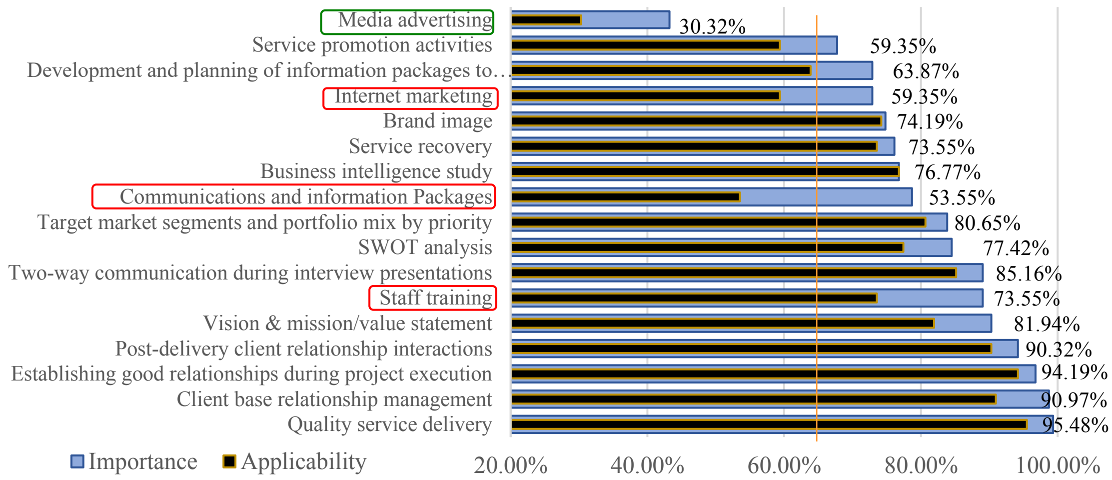

Figure 1: Importance and Applicability of Identified Marketing Activities

The results discovered that today most QSCF gave priority to deliver a quality service to their clients. Perceptive service quality directly affects clients' satisfaction, and firms always consider the accuracy of documents and attempt to conduct the project within pre-determined budget boundaries. Hence, QSCFs aim to increase client satisfaction with their services. A quality service creates the best value for clients' investments (Rajicic & Ciric, 2008). The continuous delivery of high-quality service is essential to reach clients' satisfaction, which is reflected positively in competition, and to be a profitable firm. Respondents believed, as a compulsive requirement, quality service can be delivered without much effort or management knowledge like other marketing activities. Thus, they assure a quality service delivery and promote the importance of this activity within their firms.

All four activities related to personal relationship management afforded to be in 2nd, 3rd, 4th, and 5th in applicability on the Sri Lankan QSCF. This result implies that almost all QSCFs engage in personal relationship development activities to achieve business success. An efficient relationship with clients provides the ability to deliver a service that they need, which increases clients' satisfaction and generate loyal clients to the firm. It results in increasing the client-base and ultimately enhances the business net growth. Further, personal relationship management is cost-effective marketing activity, which requires lesser staff to manage with minimum resources. This cost-effectiveness directly affects the adoption of these activities to small- and medium-scale QSCFs in Sri Lanka. Vision and mission statements captured 81.94% RII from respondents, and all respondents reported that currently, their firms have these statements. However, they were not satisfied with the robustness and actual adoption of these statements within the firms by their personnel. It needs to share a clear perception of company vision and mission statements with the internal staff.

Respondents highlighted that small-scale organisations generally do not have a management staff to carry out market research analysis and planning activities. They perform their service with few numbers of professional staff and thus, small-scale firms do not apply this activity vigorously for business development purposes. However, large-scale firms with good management capabilities commented that such activities are applied within their firms because they have a separate management staff to execute and assess business development activities. Respondents commented that their firms adopt RICS/IQSSL ethical standard framework to increase the brand image, but they did not adopt special activities to improve the brand image. This indicates that the firms are still not concerned to adopt brand image development activities, as they are confident that the brand image will automatically grow through quality service delivery. It is pertinent to state that all advertising and promotional activities are ranked as least applicable within the Sri Lankan QSCFs.It is apparent in Figure 3, the level of importance of each activity indicates a higher value compared to the level of applicability. Mainly, a high gap exists in activities such as Communication and information packages - MF1.6 (25.26%), Staff training - MF2.4 (15.48%), Internet Marketing - MF3.1 (13.55%), and Media Advertising - MF3.3 (12.91%); differences between the importance and applicability of RII values are given in the parenthesis. The main reason for this result is that these activities required additional finance and human resources. Further, constant practising of these activities is required to achieve considerable success in business growth.

4.3. MARKETING PERFORMANCE MEASUREMENT INDICATORS

A list of 11 MPM indicators was extracted from literature, and the respondents' opinions on the influence level of each indicator are presented in Table 3. According to Table 3, customer satisfaction- PM4 was the most significant influential MPM indicator for QS firms' marketing strategic decisions. Customer satisfaction measures how a firm meets or surpass a customer's expectation through the service. As a subjective and a non-quantitative MPM tool, measuring its impact is a challenging process, but many QSCF believed that customer satisfaction is a practical and a useful indicator.

Table 3: Marketing Performance Measurement Indicators

Code	Performance Measurement	Mean	Stranded deviation	RII	Overall rank
PM4	Customer satisfaction	4.645	0.661	92.90%	1
PM11	Decision accuracy	4.452	0.624	89.03%	2
PM3	Customer affinity (in terms of loyalty and retention)	4.194	0.703	83.87%	3
PM9	Number of referrals per year	3.935	0.68	78.71%	4
PM8	Customer acquisition cost	3.194	0.543	63.87%	5
PM5	Market share against competitors	2.968	0.836	59.35%	6
PM6	Mindshare (brand awareness) against competitors	2.871	0.67	57.42%	7
PM2	Cost of investments in marketing vs. benefit analysis	2.677	0.909	53.55%	8
PM10	Amount of resources (human and time) used for marketing	2.452	1.06	49.03%	9
PM7	Wallet share (share of spending on marketing efforts)	2.323	0.871	46.45%	10
PM1	Number of visitors to website	2.032	0.948	40.65%	11

Many firms measure customer satisfaction through clients' feedback on service. Customer satisfaction has a direct link with increased client referrals, which is directly linked to QS consultancy business growth. According to the literature, keeping current customers satisfied with firms' service is important than seeking new customers from a competitive market. As identified in Section 4.2, highest influential marketing activity on clients' satisfaction was 'Quality service delivery.' It seems that the way a firm identify client needs and achieving those needs within minimum resources is imperative to succeed in client satisfaction with the firm. PM11- Decision accuracy (89.03%) ranked as the second influential MPM metric, based on RII value, which has a direct link to the quality service delivery. This confirms that the output measures of operational marketing activities are at a higher importance level than others. As for cost consultancy service providers, QSs' decision highly affects the overall project cost, and accurate decisions will support to create the best output for the client's investment. PM3- customer affinity is the third highest ranked MPM indicator. Basically, this metric measures the customer loyalty and retention. It can be identified as a non-financial metric, which helps to measure personal relationship management.

Literature survey of this study explains that, when clients have an affinity towards the firm, they maintain a long-term relationship with the organisation. When a firm has a greater affinity, the marketing expeditors attract new clients from competitive market declines. With a low affinity, the firm has to spend more financial and human resources to overcome negatives and find a new customer. Research findings related to marketing applications disclosed that many QSCFs still did not apply expensive and advanced theoretical marketing practices to enhance their business performances. A majority of QSCFs have not recruited a separate marketing professional to carry out marketing practices. Hence, there is a practical barrier to conduct an advance performance measurement process without marketing professional. Furthermore, to measure the end-result of limited marketing activities, simple measuring indicators are adequate.

4.4. PERCEPTION ON MEASURING MARKETING PERFORMANCE

Table 4 demonstrates the collaboration of small-scale(staff<15) and large-scale(staff>15) QSCFs' perception of measuring marketing performance.

Table 4: Perception of Measuring Marketing Performance

Code	Indicator	Small-scale QSCF			Large-scale QSCF		
		Mean	SD	RII%	Mean	SD	RII%
MP1	Desired performance measurement of marketing will help to improve your organisations' business	4.000	0.667	80.00	4.333	0.651	86.67
MP2	Insufficient measurement reduces your team's ability to effectively communicate the marketing value to the rest of the organisation	3.526	0.612	70.53	3.750	0.622	75.00
MP3	Marketing efforts that have clear links to the overall marketing strategy are important to your organisation	3.895	0.567	77.89	4.167	0.577	83.33
MP4	Performance measurement metrics are useful to your organisation	3.158	0.765	63.16	3.750	0.866	75.00

Data analysis identified two different scales QSCFsto compare the individual opinion of 'measuring marketing performance.' A careful study of Table 4 highlights that respondents working in large-scale organisations always highly agree on given indicators than respondents from small-scale organisations. Large-scale QSCFs strongly agree that measuring marketing performance is an important marketing practice to achieve high business growth, and they strongly agreed on MP3. Further, large-scale firms moderately agreed that identified performance measurement indicators were applicable for evaluating marketing performance within their firm. However, small-scale QSCFs agreed marginally on MP4, which the importance of identified MPM indicators. The result implied that the large-scale QSCFs have a clear perception of the importance of measuring marketing performance than the small-scale QSCFs.

5. CONCLUSIONS

The study revealed that marketing is discovered as an essential ingredient in the maintenance of a profitable professional QS business and considered as part of their business development process. Quality service delivery is identified as the most important marketing activity on Sri Lankan QSCFs, while Media Advertising was found to differ from the general trend. All activities except internet marketing, service promotional activities, and media advertising, are highly applicable for QSCFs. It was identified that service promotional activities and media advertising are not applicable due to financial constraints of local QSCFs. Industry stakeholders believe that new business opportunities emerge through personal contracts, and thus, Sri Lankan QSCFs strongly absorb personal relationship management activities than internet marketing, to attract new projects from a competitive market. The majority of QSCFs were recognised that "desired performance measurement of marketing will help to enhance their business growth." The research findings suggest that marketing practices and marketing performance measurement as a compulsory component for QSCFs business growth in Sri Lanka. As such the researcher could recommend Quality service delivery, Client base relationship management, establishing good relationships with clients during project execution and Post-delivery client relationship interactions as best marketing practices for QSCFs in Sri Lanka. It was identified that the most influential marketing performance measurement indicators are Customer satisfaction, Decision accuracy, Customer affinity and Number of referrals per year. Therefore, it is recommended to use said indicators for effective and efficient marketing decision-making process.

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FACTORS AFFECTING THE SUCCESSFUL ADOPTION AND IMPLEMENTATION OF ENERGY RETROFITS IN EXISTING HOTEL BUILDINGS

M.F.F. Fasna* and Sachie Gunatilake

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Energy Efficiency (EE) of the existing buildings is identified as an important focal point for the reduction of total energy consumption and greenhouse gas emissions. Though there is a huge room for EE improvement in existing buildings, still the level of the adoption and implementation of Energy Retrofits (ER) in existing buildings is comparatively low. In fact, it has been ascertained that retrofitting existing buildings is more strenuous than constructing a new green building from scratch due to numerous factors at work that can either facilitate or hinder ER projects. Hence, this research explores the enablers and barriers for the adoption and implementation of ER projects.

Three case studies were conducted among hotel buildings that have implemented ER projects. Selected cases included two ER projects led by in-house teams and one project outsourced to an external Energy Service Company (ESCO). Altogether, 14 semi-structured interviews were conducted with different stakeholders to collect data. Findings of the research revealed 24 enablers and 42 barriers for the adoption and implementation of ER projects in existing hotel buildings. The enablers and barriers were identified for each of the three main phases of ER project implementation; i.e. pre-retrofit, retrofit implementation and post retrofit phases. 'Commitment, engagement and support from the involved parties' in all three phases of the project is ascertained as a crucial enabler that could support the successful adoption and implementation of any ER project. Conversely, 'lack of transparency about energy cost and use', 'lack of skills and experience', 'difficulties in establishing communication between parties' and 'occupancy type of the facility' were identified as the barriers that impede the ER project success in all three phases. Further, this paper argues that the party who execute the ER projects have significant impact on the enablers and barriers for the adoption and implementation of ER project. By providing a thorough understanding of the enablers and barriers, it is hoped that the findings of this study will provide a basis for more successful adoption and implementation of ER projects in the hotel sector.

Keywords: *Barriers; Enablers; Energy Retrofits (ER); Existing Buildings; Hotel Buildings.*

1. INTRODUCTION

In the contemporary world, importance of energy conservation and the reduction of greenhouse gas (GHG) emissions are stressed globally (Choi et al., 2017). Since, existing buildings encompass the largest segment of the built environment (European Climate Foundation (ECF), 2013), enhancement of Energy Efficiency (EE) in existing buildings through Energy Retrofits (ER) is crucial to attain a timely reduction in global energy usage (Ma et al., 2012). Energy retrofitting involves changing or modifying the systems, equipment or parts of a building to enhance the energy performance (Ashrafian et al., 2016; Chunduri, 2014). ER can also result in other benefits such as upgraded functionality, improved architectural quality, increased aesthetic value (Kalc, 2012), reduced resource consumption and improved indoor air quality (Alm et al., 2005).

Despite the existence of a large number of approaches and recognised benefits of retrofitting, regulating and improving the EE of the existing buildings is still considered to be a challenging issue (Hou et al., 2016). As

*Corresponding Author: E-mail – fasna.fm2013@gmail.com

highlighted by Miller and Buys (2008), retrofitting existing buildings can often be considerably more strenuous than constructing a new green building from scratch. Indeed, retrofitting existing buildings involves many challenges and opportunities (Ma et al., 2012) and there are numerous factors at work that has the potential to either facilitate or hinder ER projects (Beillan et al., 2011). This research aims to shed light on this issue by investigating the enablers and barriers for the adoption and implementation of ER in existing buildings. This paper brings together the existing literature as well as the results of the case study findings with respect to the enablers and barriers for the adoption and implementation of ER projects.

2. ENABLERS AND BARRIERS FOR THE ADOPTION AND IMPLEMENTATION OF ER

Generally, the decisions on ER are affected by several economic and non-economic motivations (i.e. enablers) and barriers (Friege and Chappin, 2014). Since still ER projects have not been implemented on a significant scale (UNEP, 2014), a number of previous researches have been carried out to determine the barriers for the adoption and implementation of ER (Moder, 2013). As the barriers of ER can be analysed at several levels, going from a broad category (e.g. financial barrier) to a more detailed and specific category (e.g. high interest rate), different authors have classified ER barriers in numerous ways. Painuly (2009) has classified ER barriers as financial, technical, information, managerial, and institutional, whereas International Energy Agency (IEA) (2003) has categorised ER barriers as information, behavioural, market, organisation and technological. On the other hand, Bruce *et al.* (2015) have classified the ER barriers as economic, regulatory and social barriers. Additionally, Zuhaib *et al.* (2017) have mentioned that ER projects encounter many social barriers throughout their adoption and implementation. So, it is clear that so far scholars have not reached a consensus on the standard classification of ER barriers. Hence, based upon the review of literature, in this research, barriers to the adoption and implementation of ER are classified as financial, technical, informational, managerial, institutional, behavioural, market, regulatory, and social.

Similarly, in the existing literature, though several authors have identified the enablers for ER projects, no one has come up with the proper classification of the enablers of ER projects. Hence, in this study, enablers of ER identified through the review of literature are categorised into several groups based upon the classification of barriers of ER projects made in some of the past researches. Table 1 provides a snapshot of the key enablers and barriers of ER projects identified through the review of literature under respective category.

Table 1: Enablers and Barriers to the Adoption and Implementation of ER

	Enabler or Barrier category								
	Financial	***Technical***	***Informational***	***Managerial***	***Institutional***	***Behavioural***	***Market***	***Regulatory***	***Social***
Barriers	Lack of funding	Immature technologies	Lack of information	Inappropriate ER project management practices	Split incentives	Reluctance to invest in ER projects	Perception of risk or uncertainty	Lack of competent regulatory body	Low level of public awareness & understandings
	Lack of access to finance	Lack of availability, reliability, knowledge on efficient technologies	Unawareness of federal & state incentives related to EE upgrades	Lack of synergy with managerial goals & incentives in business	Lack of leadership for ER projects	Inertia of current practices & attitudes	Market capacity	Lack of comprehensive national energy policy & targets	Social norms in relation to thermal & acoustic comfort, light, air quality
	Lack of incentives	Lack of access to efficient technologies	Lack of transparency about energy cost & use	Unfavourable administrative conditions	Lack of repairs or maintenance supply chain	Lack of commitment & engagement to ER	High level of uncertainty of future energy prices	Lack of legislation to support ER	Cultural change
	Lack of explicit financing mechanism & debt constraints	Lack of knowledge and know-how (Lack of technical knowledge & expertise on ER technologies/ measures & how to deploy them)		Building owners' lack of motivation to connect building performance to a clear business case for EE	Unstructured decision making or limited decision-making frequency	Occupants' resistance	Diverging priorities	Lack of willingness of the government to adequately mobilize and sensitize the public towards EE	
	Effects of lock-in	Technological incapability due to lack of adequate experts in the area of EE		Lack of skills & experience	Communication between parties is tedious & complex	Intense inter-disciplinary collaboration	Market fragmentation	Recent developments in building codes or new regulations	

	High up-front capital expenses	Difficulties in calculating the payback periods		Building operational & management constraints	Lease structures		Changing energy
	Profit sacrifices or insufficient ROI	Difficult to convince the management to undertake ER projects			Lack of proper programme design & monitoring expertise		
	Elevated payback periods	Lack of predictable roadmap for opportunities			Low versatility for intervention in existing buildings		
		Difficult to evaluate & quantify the benefits of ER			Lack of coherent green workforce development		
		Lack of inter-operability			Lack of staff training		
		Complexity of technologies			Occupancy type		
Enablers	Client resources	Availability of retrofit technologies /solutions	Awareness programmes		Building energy labelling programme	Organisation's commitment	Government policies & targets
	Financial assistance	Technical support	Demonstration programmes		Energy performance certification systems	Willingness & skills of stakeholders	Building codes & energy acts
			Knowledge of stakeholders		Green leases	Cooperation among stakeholders	

Sources: (Beillan *et al.,* 2011; Bruce *et al.,* 2015; Choi *et al.,* 2017; Davies & Osmani, 2011; Dixon *et al.,* 2014; Friege and Chappin, 2014; Hou et al., 2016; Liang et al., 2016; Ma et al., 2012; Miller and Buys, 2008; Painuly, 2009; Rhoads, 2010; Wilcox, 2010; Zuhaib *et al.,* 2017)

Although it was possible to identify the aforementioned enablers and barriers from the review of existing literature, there has been a lack of focus so far on investigating the specific enablers and barriers during each different phase of ER project implementation.

Among the available processes for the adoption and implementation of ER projects, the process suggested by Ma *et al.* (2012) has classified the overall process of a building retrofit into five major stages: namely, project setup and pre-retrofit survey; building energy auditing and performance assessment; identify possible retrofit measures or options; site implementation and commissioning; and validation and verification. Conversely, Hwang *et al.* (2015) have defined 'pre-retrofit' as the state prior to the implementation of a retrofit project and 'post-retrofit' as the state after the retrofit completion. Hence, it is possible to derive that the activities which comes prior to the implementation of selected ER measures is 'Pre-retrofit phase' whereas the activities to be performed after the implementation of ER project is 'Post-retrofit phase'. So, through careful analysis this study postulated the five major stages identified by Ma et al. (2012) into three different phases as pre-retrofit phase (i.e. project set-up and pre-retrofit survey, building energy auditing and performance assessment, and identification of ER measures), retrofit implementation phase (i.e. site implementation and commissioning) and post-retrofit phase (i.e. validation and verification). Hence, the enablers and barriers for the adoption and implementation of ER projects for each of these identified phases of ER process will be elicited in this study via the empirical investigation.

3. RESEARCH METHODOLOGY

This research adopted a qualitative case study strategy. Since hotel buildings use as much as 50% of their total expenses on energy mainly due to their 'extended operation' (Sri Lanka Energy Managers Association (SLEMA) 2009); and as the implementation of EE initiatives in the Sri Lankan hotel industry is urgently necessitated to reduce dependency on fossil fuels and meet future demand for resources like energy (International Finance Corporation Sri Lanka (IFCSL), 2013), this study has limited its focus to existing hotel buildings. Three cases (IH1, IH2 and ES1) were selected from existing hotel buildings that have successfully completed ER projects within the last five years.

In selecting cases, the focus was limited to shallow (i.e. adopting measures that are relatively easy to install and have low upfront cost) and medium (i.e. focusing on individual systems to achieve the potential energy savings of each building system) retrofits (See Chunduri 2014) only. This was because, in practice, hotel buildings rarely undertake deep retrofit projects due to their operation type. Among these selected cases, Cases IH1 and ES1 are medium retrofit projects while Case IH2 is a shallow retrofit project. In addition, in order to capture the enablers and barriers from different settings, ER projects purely handled by in-house teams as well as handled with the assistance of an external Energy Service Company (ESCO) are selected as case studies. Among the selected cases, Cases IH1 and IH2 are led by the in-house teams while Case ES1 is led by an ESCO.

In order to investigate the enablers and barriers, altogether fourteen (14) semi-structured interviews were conducted with the stakeholders involved in the adoption and implementation of ER in the selected cases. The details of the respondents are presented in Table 2.

Table 2: Details of the Respondents

Case	Respondents	Profile of the respondent	Role(s) in ER project	Experience (years)
IH1	IH1R1	General Manager of the particular hotel	Owner/Client	40
	IH1R2	Manager – Engineering of the hotel group	Facilities Manager (throughout the project)	10
	IH1R3	Chief Engineer of the particular hotel	Facilities Manager (in implementation phase & Post-retrofit phase)	39
	IH1R4	Engineer of the particular hotel	Building Services Engineer	14
	IH1R5	Engineer of another hotel attached to the particular hotel group	Energy Auditor	12
	IH1R6	Assistant Manager	Specialist Contractor, Supplier, and Architect	05
	IH1R7	Chief technical advisor – energy	Financial Institutions	25
ES1	ES1R1	Chief Executive Officer (CEO)	ESCO, Supplier, Energy Auditor, Cost Consultants	18
	ES2R2	Chief Engineer	Facilities Manager	26
	ES3R3	BMS and Facilities engineer	Building Services Engineer	03
IH2	IH2R1	Chief Engineer	Facilities Manager, Energy Auditor	30
	IH2R2	Senior Foreman	Electrical Engineer	36
	IH2R3	Foreman	Electrical Engineer	15
	IH2R4	Cost Controller	Cost Consultant	08

Code based content analysis using NVivo computer software was used to analyse the qualitative data collected through semi-structured interviews.

4. CASE STUDY ANALYSIS AND DISCUSSION OF THE FINDINGS

Case study findings revealed twenty-four (24) enablers and fourty-two (42) barriers for the adoption and implementation of ER projects in existing hotel buildings. A key gap identified in the literature review was the lack of focus on identifying enablers and barriers for the different phases of ER projects. Hence, Tables 3 and 4 presents the identified enablers and barriers for each ER project phase as well as classified into the groups given in Table 1. To present the results of the case studies (both enablers and barriers), the format presented in Figure 1 was adopted.

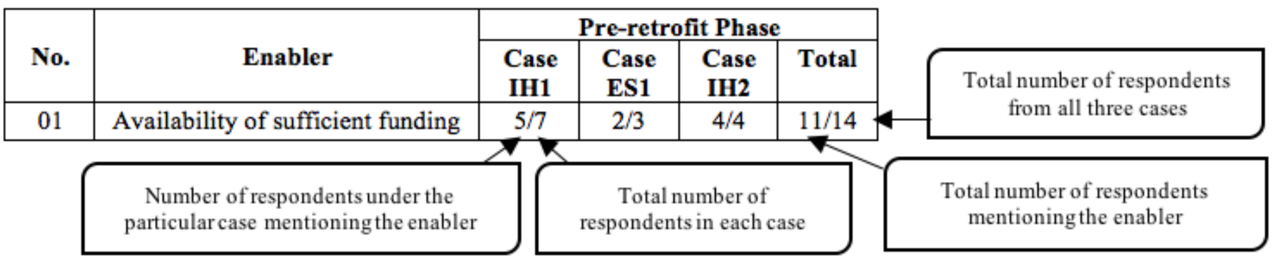

Figure 1: Presentation of the Results

The findings are presented and further discussed in the following sections.

4.1. *ENABLERS FOR THE ADOPTION AND IMPLEMENTATION OF ER PROJECTS*

As given in Table 3, out of the total twenty-four (24) enablers, twenty-one (21) enablers were identified in the pre-retrofit phase highlighting the importance of the pre-implementation phase in ensuring the success of ER project implementation. Comparatively, only eight (8) and nine (9) enablers were identified in the retrofit implementation and post-retrofit phases respectively. The identified enablers represent five (i.e. Financial, Technical, Informational, Institutional, and Behavioural,) out of the total six groups of enablers identified in Table 1. Besides, through the case study analysis 'Managerial' and 'Market' enablers were also elicited.

During the **pre-retrofit phase**, 'availability of technical knowledge and expertise to perform the assigned tasks' was identified as a key enabler by all 14 respondents from the three cases. Similarly, 'availability of sufficient funding', 'past experience with similar projects', 'availability of retrofit technologies/solutions', 'commitment, engagement, and support from the involved parties' and 'willingness and skills of stakeholders' were identified as the other enablers common to all three cases (despite whether the project was led by an in-house team or outsourced) which facilitated the effective adoption of ER in the pre-retrofit phase.

On the other hand, 'commercial guarantees provided by ESCO', ESCO's 'ability to invest in the project' and 'availability of technical support' emerged as enablers specifically when an outside contractor was involved, as was the case in ES1.

Additionally, 'financial assistance from funding agencies', 'adoption of energy performance certification schemes or standards', and 'quality of service provision' are specified as enablers only by Case IH1 in pre-retrofit phase. This would be due to certain reasons that have motivated them to adopt the ER project i.e. obtained financial assistance for the particular ER project from an international funding agency; adopted energy management standards like ISO 50001 for the facility; and quality of service provided by the specialist contractor which provided enough confidence of successfully proceeding with the implementation. Conversely, the respondents of Case IH2 disclosed that though this was their first ER project, existence of 'good project leadership for the ER project' is a unique enabler which facilitated them to successfully proceed with the pre-retrofit phase.

In **retrofit implementation phase**, findings revealed that 'availability of technical knowledge and expertise to perform the assigned tasks', 'past experience with similar projects', 'commitment, engagement and support', and 'cooperation among the stakeholders' are the enablers which assisted all three cases in successful implementation of the selected ER measures despite the party who led the project. The latter two factors were particularly stressed by the respondents from Case ES1 as crucial enablers when ER is being implemented by an external party. In contrast, Case IH2 has revealed that though at first most of the stakeholders had their own perceptions on the project, they have managed to proceed with the project implementation successfully due to the existence of sufficient 'cooperation among stakeholders'.

It was interesting to note that 'adoption of good project management practices' and 'good project leadership for the ER project' were identified as enablers during this phase only in Case ES1, which was led by ESCO. This could be mainly due to ESCOs past experience and expertise with the execution of ER projects. Conversely, 'establishment of proper communication' is an enabler ascertained in retrofit implementation phase only from Case IH1. In-house led cases i.e. Case IH1 and IH2 have divulged 'willingness and skills of the stakeholders' and 'availability of the technical support in the local context' as the enablers in the retrofit implementation phase.

In **post-retrofit phase**, case study analysis revealed that 'provision of training via conducting demonstration programmes or training programmes' and 'commitment, engagement and support from the involved parties' are the enablers unitedly disclosed by the selected cases in post-retrofit phase. Among these enablers, training/ demonstration provision is necessary in order to for the technicians to properly conduct post Measurement and Verification (M&V) once a project is implemented. This is especially crucial in organisations with little or no prior experience with ER projects as highlighted by the respondents of Case IH2.

Table 3: Enablers for the Adoption and Implementation of ER projects

No.	**Enabler**	**Number of respondents**											
		Pre-retrofit Phase				**Implementation Phase**				**Post-retrofit Phase**			
		Case IH1	**Case ES1**	**Case IH2**	**Total**	**Case IH1**	**Case ES1**	**Case IH2**	**Total**	**Case IH1**	**Case ES1**	**Case IH2**	**Total**
Financial enablers													
01	Availability of sufficient funding	5/7	2/3	4/4	**11/14**				**0/14**				**0/14**
02	Financial assistance from funding agencies	3/7			**3/14**				**0/14**	2/7			**2/14**
03	Commercial guarantees provided by ESCO		3/3		**3/14**				**0/14**				**0/14**
Technical enablers													
04	Availability of technical knowledge and expertise to perform the assigned tasks	7/7	3/3	4/4	**14/14**	6/7	3/3	3/4	**12/14**	6/7		1/4	**7/14**
05	Availability of retrofit technologies/ solutions	2/7	2/3	3/4	**7/14**				**0/14**				**0/14**
06	Existence of up to date knowledge on available efficient retrofit technologies	2/7	3/3		**5/14**				**0/14**				**0/14**
Informational enablers													
07	Conducting awareness programmes		1/3	4/4	**5/14**				**0/14**				**0/14**
08	Availability of sufficient information on energy consumption (i.e. historical data and consumption data after retrofitting)	1/7	1/3		**2/14**				**0/14**	1/7			**1/14**
Managerial enablers													
09	Past experience with similar projects	7/7	3/3	3/4	**13/14**	2/7	3/3	3/4	**8/14**				**0/14**
10	Adoption of good project management practices		1/3	1/4	**2/14**		2/3		**2/14**				**0/14**
11	Past experience with the maintenance of similar systems				**0/14**				**0/14**	1/7		1/4	**2/14**
Institutional enablers													
12	Intense need to reduce costs	3/7	1/3		**4/14**				**0/14**				**0/14**
13	Adoption of energy performance certification schemes or standards	3/7			**3/14**				**0/14**				**0/14**
14	Brand value and reputation of the particular stakeholder i.e. particular hotel, specialist contractor, ESCO	1/7	2/3		**3/14**				**0/14**				**0/14**
15	Maturity level of the specific stakeholder	1/7	3/3		**4/14**				**0/14**				**0/14**
16	Client's ability to invest in the ER project		3/3		**3/14**				**0/14**				**0/14**
17	Good project leadership for the ER project			4/4	**4/14**		1/3		**1/14**				**0/14**
18	Establishment of proper communication channels				**0/14**	1/7			**1/14**	1/7			**1/14**
19	Provision of training via conducting demonstration programmes or training programmes				**0/14**				**0/14**	4/7	3/3	4/4	**11/14**
Behavioural enablers													
20	Commitment, engagement and support from the involved parties	5/7	1/3	1/4	**7/14**	4/7	3/3	2/4	**9/14**	5/7	3/3	2/4	**10/14**
21	Cooperation among stakeholders	4/7	1/3		**5/14**	5/7	3/3	4/4	**12/14**	1/7			**1/14**
22	Willingness and skills of stakeholders	3/7	2/3	3/4	**8/14**	3/7		3/4	**6/14**			1/4	**1/14**
Market enablers													
23	Availability of the technical support		2/3		**2/14**	5/7		2/4	**7/14**				**0/14**
24	Quality of the service provision	1/7			**1/14**				**0/14**				**0/14**

Besides, 'financial assistance from funding agencies', 'availability of sufficient information on energy consumption', 'establishment of proper communication channels', and 'cooperation among stakeholders' are the enablers mentioned only by Case IH1 in post-retrofit phase. This was because, availability of sufficient information on energy consumption would facilitate the proper assessment of saving through retrofitting, while other factors are useful in ensuring the continuous operation of the retrofitted system. Conversely, 'availability of technical knowledge and expertise' and 'past experience with the maintenance of similar systems' are the enablers stated by both in-house led cases i.e. Case IH1 and IH2.

By summing up the findings on enablers, it can be derived that among the enablers which facilitated the proper adoption and implementation of ER projects, 'availability of enough technical knowledge and expertise', 'commitment, engagement, and support', 'cooperation among stakeholders', and 'willingness and skills of stakeholders' are the enablers which are crucial for the successful completion of the activities throughout the project as ER projects are huge endeavours undertaken by the organisations which necessitates the participation different stakeholders to perform various roles. Since 'commitment, engagement and support from the involved parties' is highlighted by all three cases in all three phases, it can be deduced that for any ER project despite the party who plans and execute the project, existence of 'commitment, engagement and support' throughout the project would facilitate the successful project execution (Refer Table 3). Besides, 'availability of technical knowledge and expertise' and 'past experience with similar projects' are crucial for any ER project mainly in both pre-retrofit phase and retrofit implementation phase to ensure the project success. On the other hand, if the project is led by in-house team, 'availability of technical knowledge and expertise' throughout the project is crucial to ensure the project success (Refer Table 3).

In literature, most of the authors have specified 'financial assistance' and 'government policies and targets' as the key enablers for the adoption and implementation of ER project (Refer Table 1). However, findings revealed that 'availability of sufficient funding', 'availability of technical knowledge and expertise' and 'past experience with similar projects' are the enablers that played a key role in pre-retrofit phase. Besides, 'availability of technical knowledge and expertise' and 'cooperation among stakeholders' were elicited as the main enablers in retrofit implementation phase whereas 'provision of trainings via conducting demonstration programmes or training programmes' and 'commitment, engagement and support from the involved parties' were disclosed by most of the respondents as the key enablers in post-retrofit phase. As depicted in Table 1, though 'government policies and targets', 'building codes and energy acts', 'building energy labeling programme' and 'green leases' are identified as enablers in literature, none of the respondents' have specified these as enablers for the adoption and implementation of ER projects. This could be due the lenience of country's legislations which induce low level of influence to adopt ER projects.

4.2. BARRIERS FOR THE ADOPTION AND IMPLEMENTATION OF ER PROJECTS

Through case study analysis, fourty-two (42) barriers that could hinder the adoption and implementation of ER were identified (Refer Table 4). The most number of barriers (i.e. 27) were identified in the pre-retrofit phase, while seventeen (17) and sixteen (16) barriers each were identified in retrofit implementation phase and post-retrofit phase respectively. The identified barriers represent eight (i.e. Financial, Technical, Informational, Managerial, Institutional, Behavioural, Market and Social) out of the total nine groups of barriers identified in Table 1.

In **pre-retrofit phase,** 'difficult to evaluate and quantify the benefits of retrofitting' is the key barrier specified by Case IH1 in pre-retrofit phase due to lack of up to date information on cost and benefits of different ER measures. Similarly, Case ES1 has revealed that 'lack of technical knowledge and expertise' of the in-house team is a key barrier that they have encountered due to which they have decided to obtain the assistance of ESCO for the ER project while 'lack of trust and confidence on ESCOs' is another the key barrier they have faced due to which they had to investigate the sustainability credential of the particular ESCO. Conversely, 'lack of commitment and engagement to ER project' is the key barrier highlighted by Case IH2 in pre-retrofit phase due to their employees' lack of prior experience with ER projects and poor understanding of the benefits that could be gained through retrofitting.

Table 4: Barriers for the Adoption and Implementation of ER projects

No.	**Barrier**	**Number of respondents**											
		Pre-retrofit Phase				**Implementation Phase**				**Post-retrofit Phase**			
		Case IH1	**Case ES1**	**Case IH2**	**Total**	**Case IH1**	**Case ES1**	**Case IH2**	**Total**	**Case IH1**	**Case ES1**	**Case IH2**	**Total**
Financial barriers													
01	High up-front capital expenses	3/7			3/14				0/14				0/14
Technical barriers													
02	Lack of knowledge on efficient retrofit technologies	1/7	1/3		**2/14**				**0/14**				**0/14**
03	Lack of technical knowledge and expertise	1/7	3/3		**4/14**				**0/14**	1/7			**1/14**
04	Difficult to convince the top management to undertake ER projects	1/7	1/3	3/4	**5/14**				**0/14**				**0/14**
05	Lack of predictable roadmap to identify the opportunities	4/7			**4/14**				**0/14**				**0/14**
06	Difficult to evaluate and quantify the benefits of retrofitting	5/7			**5/14**				**0/14**	1/7	1/3	4/4	**6/14**
07	Lack of access to certain technological platforms or software				**0/14**				**0/14**	1/7			**1/14**
08	Difficulties in attaining the expected savings									1/7	1/3		**2/14**
Informational barriers													
09	Lack of information (lack of availability of energy consumption data)	2/7			**2/14**				**0/14**	1/7			**1/14**
10	Lack of transparency about energy cost and use	2/7	1/3	3/4	**6/14**	1/7			**1/14**	1/7			**1/14**
11	Unawareness of locally available incentives for energy conservation projects	4/7	1/3		**5/14**				**0/14**				**0/14**
12	Lack of accuracy and reliability of available data	1/7			**1/14**				**0/14**				**0/14**
Managerial barriers													
13	Poor project management practices				**0/14**	4/7		3/4	**7/14**				**0/14**
14	Delays in getting the ordered equipment		1/3		**1/14**			3/4	**3/14**				**0/14**
15	Delays in getting the approval from the local authority				**0/14**	5/7			**5/14**				**0/14**
16	Interruptions to building operation and management				**0/14**	4/7	2/3		**6/14**				**0/14**
17	Lack of skills and experience			3/4	**3/14**	2/7	2/3	4/4	**8/14**	4/7	2/3		**6/14**
Institutional barriers													
18	Unsystematic way of making decisions	4/7		2/4	**6/14**	4/7			**4/14**				**0/14**
19	Lack of leadership for ER projects	3/7			**3/14**				**0/14**			1/4	**1/14**
20	Difficulties in establishing communication between parties	1/7	1/3		**2/14**		1/3		**1/14**	1/7			**1/14**
21	Lack of programme design expertise		1/3	3/4	**4/14**				**0/14**				**0/14**
22	Lack of proper programme monitoring expertise				**0/14**				**0/14**		3/3	4/4	**7/14**
23	Low versatility for intervention in existing buildings	4/7			**4/14**				**0/14**				**0/14**
24	Lack of staff training				**0/14**				**0/14**	2/7			**2/14**
25	Occupancy type of the facility which caused, ▪ Difficulties in conducting the audits ▪ Difficulties in properly identifying the energy saving from the retrofitted system	1/7			**1/14**	3/7	3/3	4/4	**10/14**	1/7			**1/14**
26	Lack of time		2/3		**2/14**				**0/14**				**0/14**
27	Lack of proper coordination				**0/14**	1/7	2/3		**3/14**				**0/14**
28	Non-conductance of post occupancy assessment				**0/14**				**0/14**			3/4	**3/14**

Behavioural barriers													
29	Reluctance to invest in ER projects	1/7			**1/14**				**0/14**				**0/14**
30	Lack of commitment and engagement to ER projects		1/3	4/4	**5/14**			2/4	**2/14**			2/4	**2/14**
31	Difficult to change the attitude of the staff			3/4	**3/14**			4/4	**4/14**				**0/14**
32	Intense inter-disciplinary collaboration				**0/14**	4/7	2/3		**6/14**				**0/14**
33	Negligence of the stakeholders which caused system errors				**0/14**	3/7	1/3		**4/14**				**0/14**
Market barriers													
34	Perception of risk or uncertainty		2/3		**2/14**				**0/14**				**0/14**
35	Lack of trust and confidence on ESCOs	2/7	3/3		**5/14**				**0/14**				**0/14**
36	Difficulties in finding reliable source of advice			2/4	**2/14**				**0/14**				**0/14**
37	Difficulties in selecting the most suitable supplier			1/4	**1/14**				**0/14**				**0/14**
38	Difficulties in finding certain ancillaries needed for the implementation				**0/14**	2/7			**2/14**				**0/14**
39	Uncertainty of the availability of the needed resources to run the retrofitted system				**0/14**				**0/14**	2/7			**2/14**
Social barriers													
40	Low level of public awareness and understandings				**0/14**	3/7			**3/14**				**0/14**
41	Social norms with respect to the thermal and acoustic comfort, light and air quality			1/4	**1/14**				**0/14**				**0/14**
42	Negative perception regarding the project				**0/14**	1/7			**1/14**	4/7			**4/17**

Analysis of the findings revealed that, 'difficult to convince the top management to undertake ER projects' and 'lack of transparency about energy cost and use' are the barriers mentioned by all three cases in pre-retrofit phase. Since Case IH1 had to develop the needed support infrastructure for the retrofitted system and as this particular ER project was initially led by head office team as a whole, in this phase 'high up-front capital expenses' and 'lack of leadership for ER project' are the unique barriers faced by this case. Conversely, 'lack of time' of the in-house staff to plan and execute the ER project, and 'perception of risk or uncertainty' are the distinctive barriers which led Case ES1 to plan and execute their ER project using ESCO. On the other hand, Case IH2 has disclosed that 'lack of skills and experience', 'difficult to change the attitude of the staff', 'difficulties in finding reliable source of advice', 'difficulties in selecting the most suitable supplier', and 'social norms with respect to the thermal and acoustic comfort, light and air quality' are the barriers uniquely faced by them in pre-retrofit phase mainly owing to their lack of previous experience with ER projects. Besides, 'unsystematic way of making decisions' is the one and only barrier faced by both in-house led projects i.e. Case IH1 and IH2, which insist the vitality of mapping the decisions to be made throughout the project and get the needed consultations from the respective parties in in-house led projects prior to make decisions.

In **retrofit implementation phase**, Case IH1 which had to get certain approvals from local authority, has faced certain 'delays in getting approval from the local authority' due to the negligence of the respective authorities. Case ES1 which is led by ESCO has specified that 'occupancy type of the facility' is the barrier that they have encountered while retrofitting the facility. Equally, Case IH2 has mentioned that 'lack of skills and experience' of the in-house staff with implementation of the selected ER measures, 'occupancy type of the facility', and 'difficult to change the attitude of the staff' were the key barriers that they have encountered.

Since all three ER projects are being done in hotel facilities which have 24/7 operation and as in-house team of the selected cases did not have enough expertise with the implementation of particular ER measures, 'lack of skills and experience' and 'occupancy type of the facility' are being highlighted as the barriers encountered by all three cases in retrofit implementation phase. On the other hand, 'poor project management practices' is the barrier faced only by both in-house led cases i.e. Case IH1 and IH2 in retrofit implementation phase, which indirectly implies the existence of lack of knowledge with the in-house staff about the way to run an ER project and thereby insist the need of adopting a good approach to manage the ER project. Besides, 'difficulties in establishing communication between parties' is the barrier highlighted by Case ES1 in retrofit implementation phase since in this case the project is mainly led by an ESCO but along with the involvement and consultation of the in-house employees.

As the total cost of the project and most suitable financing options are determined in pre-retrofit phase and as in retrofit implementation phase physical implementation of selected ER measures takes place, the possible influence of financial and technical aspects in implementation phase would be very low. Similarly, in this phase, none of the cases have specified financial and technical barriers while 'lack of transparency about energy cost and use' is the one and only informational barrier reported by Case IH1.

In **post-retrofit phase**, 'lack of skills and experience' for the staff to properly operate the newly implemented system, and neighbourhood's 'negative perception regarding the project' (i.e. neighbourhood's fear of boiler explosion) are the key barriers highlighted by Case IH1. Similarly, the key barrier faced by Case ES1 in post-retrofit phase is 'lack of proper programme monitoring expertise' which has insisted the ESCO to establish a proper M&V protocol as well as to assist the client in doing M&V. Case IH2 which did not have prior experience with retrofitting have specified that 'difficult to evaluate and quantify the benefits of retrofitting' and 'lack of proper programme monitoring expertise' are the key barriers that they have faced.

Since in hotel buildings occupancy pattern tend to change time to time, all three cases have found 'difficulties in evaluating and quantifying the benefits of retrofitting'. Conversely, 'lack of technical knowledge and expertise', 'lack of access to certain technological platforms or software', 'lack of information (lack of availability of energy consumption data)', 'lack of transparency about energy cost and use', 'difficulties in establishing communication between parties', 'lack of staff training', 'occupancy type of the facility', 'uncertainty of the availability of needed resources to run the retrofitted system', and 'negative perception regarding the project' are the barriers which hindered the effective execution of the tasks only in Case IH1 in post-retrofit phase. On the other hand, the barriers faced only by Case IH2 in post-retrofit phase mainly due to their lack of prior experience with execution of ER are 'lack of leadership for ER projects', 'non-conductance of post occupancy assessment', and 'lack of commitment and engagement to ER projects'.

Financial barriers were not being encountered by any of the selected cases in post-retrofit phase since in post-retrofit phase no any significant amount of cost needed to be incurred. Technical barriers and institutional barriers are the barriers highlighted by selected cases in post-retrofit phase while the other types of barriers were being rarely mentioned. For instance, 'lack of skills and experience' is the one and only managerial barrier faced by selected cases i.e. Cases IH1 and ES1 in post-retrofit phase. Similarly, 'lack of commitment and engagement to ER project' faced by Case IH2 is the only behavioural barrier affirmed in this phase. Equally, 'uncertainty of the availability of the needed resources to run the retrofitted system' is the one and only market barrier ascertained in this phase while 'negative perception regarding the project' is the only social barrier identified in this phase and are faced by Case IH1.

In brief, though some regulatory barriers were elicited through the review of existing literature (Refer Table 1), the case study analysis did not identify any barriers relating to the regulatory aspects and thereby disclosed their lack of impact on the project success. As given in Table 1, 'high up-front capital, 'lack of information', 'lack of access to finance' and 'lack of knowledge and know-how' are highlighted by most of the authors in the existing literature as the main barriers for the adoption and implementation of ER projects. However, the analysis of the findings disclosed that these barriers impact the retrofit projects in different ways during the different project phases. For instance, 'lack of transparency about energy cost and use' and 'unsystematic way of making decisions' are the barriers highlighted by most of the respondents in pre-retrofit phase, while 'poor project management practices', 'interruptions to building operation and management', 'lack of skills and experience', 'occupancy type of the facility', 'intense inter-disciplinary collaboration' are being stressed by the respondents in retrofit implementation phase. Conversely, 'difficult to evaluate and quantify the benefits of retrofitting' and 'lack of skills and experience' were divulged by respondents as the key barriers in post-retrofit phase.

As a whole, among the derived enablers in this study, thirteen (13) enablers are consistent with the literature while rest of the enablers are purely ascertained through the case study analysis (Refer Tables 1 and 3). Conversely, among the barriers identified through the case study analysis, most of the barriers i.e. twenty-eight (28) barriers seem to be in-line with the barriers compiled from the literature review, while rest of the fourteen (14) barriers are identified mainly via the case study analysis (Refer Tables 1 and 4). Besides, among the barriers derived through the literature, most of the barriers i.e. thirty-one (31) are not being divulged by the case study respondents and thereby clearly distinguishes the barriers that can impede the success of ER projects in the local context (i.e. Sri Lankan context).

5. CONCLUSIONS

This paper identified the enablers and barriers that influence the adoption and implementation of ER projects using three case studies. In total, seven (7) groups of enablers and eight (8) groups of barriers were identified (Refer Tables 3 and 4).

Among the 24 enablers identified, the research suggests that for any ER project, 'commitment, engagement and support from the involved parties' throughout the project is crucial to facilitate the successful project execution while 'availability of technical knowledge and expertise' and 'past experience with similar projects' are crucial in both pre-retrofit and retrofit implementation phases to ensure the project success. Further it has been ascertained that in in-house led ER projects 'availability of technical knowledge and expertise' throughout the project is vital to ensure the project success.

Altogether, forty-two (42) barriers that can impede the successful adoption and implementation of ER projects in existing hotel buildings was also identified. Herein, 'lack of transparency about energy cost and use', 'lack of skills and experience', 'difficulties in establishing communication between parties' and 'occupancy type of the facility which caused difficulties in conducting the audits and difficulties in properly identifying the energy saving from the retrofitted system' are the barriers which had significant impact in impeding project in all three phases. Besides, the possibility of encountering commitment issues (i.e. lack of commitment and engagement to ER projects) in all three phases of ER project by the organisations who do not have prior experience with retrofitting is also being ascertained through case study analysis.

Further, this research has made it vivid that the pathways to the implementation of ER project is complex and insisted that the further research in this arena should investigate the strategies that can be used to overcome the identified barriers. Although this research was limited to only three cases, valuable insights gained provide industry practitioners with a set of enablers and barriers to be considered when pursuing ER projects. This research can help industry practitioners in understanding the enablers and barriers for the adoption and implementation of ER projects and accordingly ensure success.

6. ACKNOWLEDGEMENT

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GREEN BUILDINGS AND WELL-BEING OF EMPLOYEES IN COMMERCIAL SPACES

James Hartwell, Matthew Tucker and Mohan Siriwardena*

Department of Built Environment, Liverpool John Moores University, United Kingdom

ABSTRACT

As recently as forty years ago, the Facilities Management profession was relatively unknown in the built environment industry. Buildings were generally maintained serviced and cleaned. The Facilities Management profession is now one of the fastest growing professions in the UK and as a result, there is a growing list of services to provide, including delivering on environmental commitments and sustainable practices. This research adds to the growing body of literature on the profound effects sustainable buildings can have on its occupants and converts these benefits into financial metrics which benefit both landlords and tenants of commercial buildings. Although there is conclusive evidence of the benefits, there is still a perception that building green does not represent value for money. This paper aims to investigate to what extent facilities managers are responsible for introducing sustainable initiatives that enhance the health well-being and productivity of employees. To achieve this aim, primary data was gathered through face to face interviews with Facilities Management professionals.

The findings reveal that although sustainability was viewed as important and is highly valued by most organisations, there are more important priorities to focus on. The results from the interviews found that 100% percent of the organisations who participated had sustainability policies in place and the main drivers for introducing those policies was to comply with legislation and to provide a healthier, more attractive workplace for their employees. Although sustainability and the health, well-being and productivity of employees was a main driver, as well as being embraced and promoted by Facilities Managers, ultimately, they felt that they had more important responsibilities to focus on, hence it did not feature as a priority in their day to day job. This was also identified as one of the main barriers for sustainable Facilities Management to improve, as well as cost, the current skillset and knowledge of Facilities Managers.

Keywords:*Facilities Management; Green Buildings; Health, Well-being and Productivity; Sustainability.*

1. INTRODUCTION

The subject of sustainability and sustainable development has generated a vast amount of literature in recent years, especially from the built environment industry, which is believed to be accountable for almost 50% of the UK's CO_2 emissions aswell as 50% of water consumption (Cotgrave and Riley, 2013). The most widely accepted definition of sustainable development is from the Bruntland Report (1987), which describes it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Over the last two decades, as organisations became a lot more aware of their environmental commitments and began to incorporate sustainability principles into their core business strategy, multiple claims emerged that green buildings can have profound effects on the health, well- being and productivity of employees occupying those buildings. Although these claims from researchers such as Vivian Loftness *et al*., (2003), Browning *et al.,* (2012) and WGBC (2013) were supported with calculated findings and clear evidence, resistance still remains from viewing sustainability as a strategic priority at the design stage of construction projects. As staff salaries and benefits can typically account for up to 90% of a typical business operating costs (Edwards & Naboni, 2013), the health, well-being and productivity of employees should be a high priority for any organisation. As Facilities Managers have a significant influence

*Corresponding Author: E-mail - m.l.siriwardena@ljmu.ac.uk

of how buildings are controlled and operated every day, they are in a unique position to strategically develop and implement an organisations commitment and contribution to the sustainability agenda. However, Facilities management is still a relatively new found profession within the property and construction industry, and although Facilities Managers are in a position to improve the environmental performance of their business, as well as employee productivity, it ultimately depends on how much Facilities Management is valued and involved at a strategic level within an organisation.

This issue led to the aim of this research, which was to critically investigate the extent Facilities Management can strategically influence sustainable initiatives within commercial organisations, in order to optimise the health, well-being and productivity of employees.

2. GREEN BUILDINGS

The term green building has attracted a vast amount of literature in recent years as the built environment can affect the people who occupy buildings every day as well as the wider natural environment. The definition of a Green building has been widely discussed internationally and can be defined by US Environmental Protection Agency as the practice of creating structures which are resource efficient and environmentally responsible throughout a buildings lifecycle. Whereas Chinas Green Building Evaluation standard defines a green building as a building which provides healthy, productive, practical, highly efficient use of space whilst saving resources such as land, energy, water and protecting the environment. The difference in the two definitions highlights the different perceptions of what a green/sustainable building is, from being just environmentally responsible and resource efficient, to recognising that green buildings can deliver so much more if viewed holistically, resulting in economic, social and environmental benefits.

Literature generally agrees that sustainability is looked at from a triple bottom line perspective: Economic, Environmental and Social. The priority of each circle has been widely discussed and there has been much debate over whether they should be used equally or not. According to (Boyd, 2006) in order for a meaningful triple bottom line assessment of an organisations built assets, an equal balance of economic, social performance aswell as environmental protection factors should be evaluated.

While the environmental benefits of green buildings have been well documented over the last two decades, the emphasis appears to be shifting from ‘planet’, to ‘people’ and ‘profit’ as a deeper understanding of the triple bottom line value of green buildings has developed across different industries, particularly the commercial sector. (WGBC, 2014)

Across the UK, offices account for approximately 102 million m² of floor space with 83% of this being classified as commercial offices, with the bulk of the remainder being local government-occupied buildings (ONS, 2016). Over a 10- year period between 2001-2011 commercial offices expanded at the fastest rate in comparison to retail and industrial sectors, with a total increase in floorspace of 29%. (ONS, 2016).

The subject of sustainability has significantly increased in the commercial office sector in recent years. Greater awareness and recognition especially among stakeholders, such as building owners, developers, investors, and the public sector has placed sustainability as a high priority worldwide. Following a report by GVA (2012), It concluded that sustainability was no longer just ‘nice to have’, but in order for the property sector to retain its long-term value, ensuring that sustainability is a high priority will need to continue. One of the main challenges for developers, investors and building owners for building green is how it represents value for money in comparison to a conventional office building. Increasing evidence is appearing on the numerous benefits a green building can have, not just on the environment, health and well-being of employees, but also financial benefits.

Asset Value

Studies around the world have shown a pattern emerging that green buildings can attract a financial premium in terms of rental and sales value and could be more attractive to tenants and future occupiers, which is driven by lower operating costs, higher occupancy rates and lower yields. An example of some of the international studies can be found in Newell *et al*. (2014) and Chegut *et al*. (2014). These studies found that in the sale of certified buildings compared to non-certified buildings, sale price premiums were in the range of 0%-30%. Also, the study found that the higher the certification of the building, the higher the sales premium was.

Operating Costs

Green buildings saving on operating costs over the course of the buildings lifecycle is often seen as the most recognised benefit of green buildings as numerous studies have shown that commercial buildings can save on costs by reducing the amount of energy and water used, as well as lowering long term maintenance costs. The reduction in energy usage in certified buildings compared to non-certified buildings ranged from 25% - 30% in Kats (2003). Similar to this study, Kats (2010) found that the higher levels of certification, often related to the highest percentages of energy and water savings.

Reduced Absenteeism

One of the less obvious financial benefits of green buildings in the commercial sector is the costs which can be saved by reducing the amount of days employees are absent from work, aswell as retaining existing employees. The design of the office can have a significant effect on the health, well being and productivity of employees, which is discussed further in the next chapter. Studies such as Sing *et al.* (2010) have found that employees cannot work as effectively when they are ill, have little motivation and high stress levels, which results in employees taking sick days due to illness and stress. In the UK alone, over 50 million days where lost in 2015 due to employees being absent from work, just for reasons including minor illnesses, stress, depression, anxiety, headaches and migraines (ONS 2016). Absence through sickness can come at a major financial cost to organisations. Taking into account that the average wage in the UK in 2015 was £26,500 (ONS 2016), the total cost companies would have paid employees to be absent in 2015 alone, would have been just under £6b.

Employee Turnover

Employee turnover can be costly for any organisation. A generally accepted figure of the true cost of replacing an employee is approximately 1.5 – 2 times the employee's salary (Heschong 2003). Costs can be accumulated throughout a number of different processes, from the termination cost, recruitment agency costs, time spent interviewing, negotiations and lost productivity. The cost could eventually be greater if for example in knowledge sectors where the competitive edge and advantage is the human expertise. Also, once a new employee is eventually hired it can be argued that he/she may only be working at around 50% within the first 6 months whilst undergoing inductions, training and becoming familiar with the role and organisation.

An example of how green buildings can result in significant savings due to employee turnover is shown in a report by CBRE 2009 which found that, recruitment of new employees, public image and retention of existing employees where all enhanced in green buildings. In order to gain financial benefits from designing/retrofitting a green building, it has to be designed with people in mind, designing from the inside out, focusing on the people just as much as the planet, which will in turn, result in profit.

Relationship between the Office Building and its Users

Gensler (2005) Argues that British businesses have always perceived the office as an overhead, with the result that minimising costs often determine the shape of Britain's workplace, rather than focusing on creating an enjoyable and productive working environment for the buildings occupiers. Since buildings are built predominantly for human occupation, and given the fact that up to 90% of a typical business operating costs comes from staff salaries and benefits, with 9% rental costs and just 1% energy costs, the benefits a green building could have on employee productivity and bottom line benefits should not be ignored. Considering the percentages of a typical business operating costs over its life- cycle, the cost of employing people far outweighs the cost of maintaining and operating the building over its lifecycle, which is why investing in improving the work environment could be the most efficient and cost effective method of improving productivity.

There is overwhelming evidence in the commercial sector which indicates that the design of the office can impact on the productivity and the health and well- being of its occupants. WGBC (2014) highlight the key priority areas of a green building which can influence health, well-being and productivity of employees as Indoor Air Quality (IAQ), Thermal comfort, Lighting and daylight, Acoustics, and Interior layout and Active Design.

3. FACILITIES MANAGEMENT

Facilities Management has many definitions due to the dynamic nature of FM and its rapid development as a profession. However, one of the most widely accepted definitions in the UK is from BIFM who define it as the integration of processes within an organisation which maintains and develops the agreed services which support and improve the effectiveness of its primary activities.

The profession and role of Facilities Managers has evolved over the last three decades, they are longer just thought as building managers responsible for day to day operations such as cleaning and maintenance. Instead, it is being recognised as a strategic business function with a growing list of services to provide to support organisations core business in both the long term and short term. Due to this rapid progression it is now one of the fastest growing membership associations in the UK and the FM market is set to rise to £117b by the end of 2017. One area that has developed interest in the FM industry in recent years is the facilities manager's role in adding value to an organisation by delivering sustainable practices.

Sustainable FM

As the subject of sustainability has grown in significance across many businesses, organisations are becoming more aware of the effect their business activities are having on economic, environmental and social issues, and are now incorporating sustainability policies into their reports (Lindsey 2011; KPMG 2008). Sustainable Facilities Management can therefore be described as the process of managing, implementing and delivering an organisations non- core business activities aswell as integrating the people, place and business of an organisation which will optimise environmental, economic and social benefits of sustainability.

Although Facilities Managers are in direct control of how a building and its facilities are controlled every day, and are in a position to influence the health, well-being and productivity of those working in the office environment, it is not clear which of the drivers, issues and responsibilities are most important for FM to develop skills and knowledge in. (Kwawu & Elmualim, 2011)

Sustainable FM Policies

In order for Facilities Managers to be in a position to significantly influence the health, well-being and productivity of employees, it has to be a key driver and be a part of an organisations sustainability policy. Until recently, research of organisations drivers to implement a sustainability policy have not been documented, but with recent economic downturns and ever tightening legislation regarding carbon emissions, organisations are now beginning to integrate sustainability issues into their policies as they are expected to be part of delivering on environmental commitments

Recent studies by GVA (2014), GVA (2016), Elmualim *et al* (2010) and Price *et al (*2011) have all analysed to the extent to which organisations adopt a sustainability policies and strategies, with many organisations not believing sustainability to be a high priority, only being 'of some importance' and viewing sustainability as just an 'add on'.

Key Drivers for Introducing Sustainability Policies

An organisations sustainability policy directly influences the Facilities Managers responsibilities (Kwawu & Elmualim, 2011), so depending on where staff productivity ranks on the sustainability agenda, this could be a challenge for the FM to have an influence on improving the productivity and the health and well-being of employees. As the built environment accounts for approximately 40% of global natural resources which are used, aswell as 40% of global waste and gases that are produced, sustainability policies in the past have previously been influenced by legislation and the proliferation of energy and carbon footprint related issues.

Studies from Kwawu and Elmualim (2011), GVA (2014) all found that increasing legislative pressure was the key driver for undertaking sustainability assessments and implementing sustainability policies. However, in GVA (2016), client pressure and occupier demand overtook government legislation as the key driver for introducing sustainability policies within organisations. Results show how occupier demand has increased by 100% in the space of 5 years, highlighting the fact that building occupiers and clients want to be associated with and occupy sustainable buildings.

Now that the key drivers for an organisation to implement a sustainability policy are not as influenced by increased legislative pressure, in comparison to the previous years, the facilities manager's sustainability responsibilities may change. In a study from Kwawu and Elmualim (2011), where legislative pressure was the key driver as shown in Figure, the facilities managers responsibilities where directly influenced by this, with the top 2 responsibilities being waste management and energy management (Figure 1). The productivity of employees was not regarded as an important responsibility for the facilities manager, ranking down in 11th place.

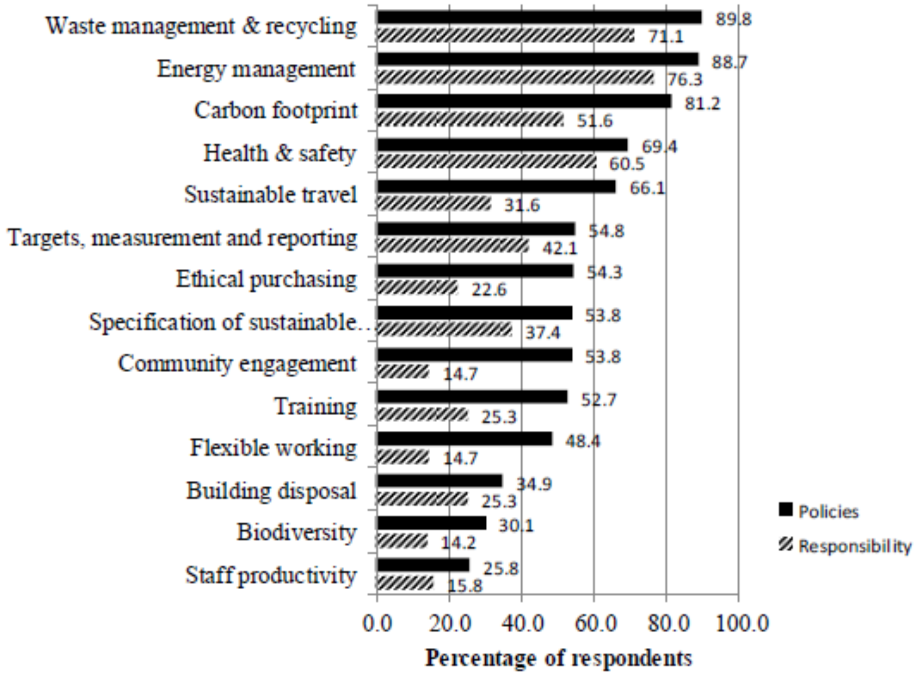

Figure 1: FM Sustainability Responsibilities (Adapted from: Kwawu & Elmualim, 2011)

Although Facilities Managers are in key a position to influence and add value to an organisations sustainability agenda, a more holistic approach is needed to recognise equally important issues like the health, well-being and productivity of employees. Having a productive work environment is an important factor for an organisations productivity and with the FM being in direct control over the building environment, the responsibility of the FM should be significant. The reasons for employee responsibility not being regarded as a high priority for facilities manager can be linked back to Elumalim *et al* (2010) which identified the main barriers for sustainable FM as lack of knowledge, lack of senior management commitment and time constraints.

Knowledge and Skills Barrier

A common challenge which appears in the literature for the future progression of sustainable FM is the current skill set, knowledge and experience of Facilitates Managers (Elmualim *et al*.,2010; Shah 2007). As the FM profession is experiencing a period of rapid growth and complexity regarding the functions of a FM, they highlighted the fact that facilities managers need to have a seat at the table during any discussions where significant changes occur throughout the buildings life-cycle. However, in order to be present during meetings, and to be able to successfully implement sustainability policies, they need to be highly qualified professionals who are capable of understanding the complexities of green buildings and their operation.

Value of Facilities Management within an Organisation

Similarities in the literature from (Hodges 2005; Elmualim *et al*., 2010) found that one of the most important issues in FM is how much FM is valued as a strategic priority within the organisations culture, and how well it is used to contribute to the bottom-line of the organisation. If FM is valued within the organisation, the work required to implement sustainability policies and practices can be more easily achieved but in contrast to this, (Elmualim 2010) found that the undervaluation of the contribution FM can make to the success of an organisation, was responsible for the lack of success of sustainable FM. Finance also plays a part in the attitude towards how an organisation runs its Facilities Management department and whether they are treated as assets or not. This could then dictate the organisations attitude towards sustainability issues and how receptive they would be towards making changes.

4. RESEARCH METHOD

Overall research approach was based on multiple case studies (Yin, 2009). Research design adopted a broadly qualitative and inductive. Rather than analysing and gathering data from a specific group, it is more appropriate for this study to gather data from individuals from different organisations to assess how much each FM department is valued within each organisation, where sustainability ranks as a strategic priority and to evaluate the different views towards the responsibility of employee productivity. For this study, a collective case study approach has been adopted to provide a more balanced and valid approach and to achieve strong conclusions.

The unit of analysis is still the organisations with an in-house FM department, but will also be organisations who provide FM services on behalf of clients who find that outsourcing is more effective. By selecting to interview both in house Facilities Managers as well as Facilities Manager Consultants, it will provide more accurate data of the nature of the Facilities management industry. This also allows to study the facilities managers in their real life setting, as the common denominator between in house Facilities managers and facilities management consultants is that they all manage FM services within a real life setting for a client, or on behalf of a client. The size and nature of organisations who participated in the study, as well as the level of each participant are presented in Table 1.

Table 1: Research Participants Overview

	Nature of Organisation	Size of Organisation	Type of Organisation	Level of Superiority
Participant 1	In house FM	Large	University	Facilities Manager
Participant 2	FM consultant	Large	Commercial Real Estate providers	Facilities Manager of Asset services
Participant 3	In house FM	Small	Charitable Organisation	Associate Director of FM
Participant 4	In house FM	Medium	Football club	Facilities Manager of football stadium
Participant 5	FM consultant	Medium	FM providers	National Operations Director

Empirical data were collected through semi-structured interviews and were subjected to a code based thematic analysis.

5. FINDINGS AND CONCLUSIONS

The aim of this research was to conduct an investigation into the relationship between green buildings and the health, well-being and productivity of employees within commercial office space. The rationale behind selecting this topic for investigation was due to multiple claims in recent years which suggested that green buildings and their indoor environmental characteristics can have profound effects on the health, well-being and productivity of employees, which result in significant bottom line benefits. As Facilities Managers are in direct control of how buildings and its facilities are managed and controlled every day, they are in a unique position to influence the health, well-being and productivity of those working in commercial offices.

There is overwhelming evidence in the commercial sector which indicates that the design of the office can impact on the productivity and the health and well- being of its occupants. By investing in the upgrade to a green building and designing the building from the inside out, focusing on the people just as much as the planet and profit, this can result in financial benefits to both landlords and tenants, which are; could attract a financial premium in terms of rental and sale value, could be more attractive to future tenants and occupiers which would mean the building would be vacant for less, ability to secure finance for the development from Energy Efficiency Financing (EEF) schemes, quick return on investments, lower maintenance costs. Benefits to the tenants of green buildings are; reduced absenteeism, reduced employee turnover, employee recruitment, lower operational costs and improved productivity.

Although there is substantial evidence for each of these points and various other green building benefits, resistance still remains from building green, largely due to the behaviours of real estate investors and occupiers, and that building green is a lot more expensive than a conventional building. By incorporating green strategies from an early stage in construction and refurbishment projects, it will cost considerably less than more expensive 'bolt on' strategies where sustainable features and enhancements are added after the design stage. An example of adopting green strategies from the design stage is an integrated design approach, reducing the energy demand from the building by a passive design philosophy, reducing the heat loss through a thermally efficient skin and predominantly relying on natural ventilation and lighting.

After critically analysing the data gathered from the literature review and interviews, it appears Facilities Management is starting to get the recognition it deserves at a strategical level, especially for medium-large organisations with tall organisational structures and their own in house FM departments. Although it still appears to be a work in progress, the world is changing in regards to FM internally and externally, with a lot more drivers for FM's to become more strategic. In some cases, organisations are now beginning to involve Facilities Managers from the design stage of construction projects and have a seat at the table, instead of being involved after the handover stage, which was an issue mentioned by Shah (2007). A challenge for FM to further progress is still from the senior management level, recognising that FM should be something that is thought of strategically, invest in and monitor. Although it is showing signs of progression and organisations appear to becoming more aware, the same cannot be said for organisations who outsource their FM services. There is still a lot of room for improvement in this area as FM consultants were not involved in key strategic decision making on behalf of the clients they represent. It was found that the FM providers were strictly only involved in the operational stages such as the day to day management of operations and services. It is unclear what the reasons for this are, however there were a number of deciding factors such as whether they may have their own internal FM structure or they may want to run the facilities at the lowest cost.

In order for Facilities Managers to be able introduce and successfully implement sustainable initiatives in the workplace to enhance the health, well-being and productivity of employees, sustainability has to be a key driver and highly valued by organisations and not just seen as 'nice to have'. The comparison of studies in the literature review indicated that organisations are becoming more aware of their environmental commitments and becoming more aware of the benefits of being a sustainable organisation by the increase in organisations adopting sustainability policies. These findings were also similar in this study as 100% of organisations had policies in place, although not necessarily successfully implemented. There is also similarities in the research from Pitt *et al.* (2009) who found that most organisations who had sustainability policies were medium to large sized. Although it appeared to 'highly valued' by most organisations in this study, it was only regarded as a strategic priority for the large organisations. It is therefore concluded that those organisations who place sustainability high on the agenda and drive it through the organisation from a senior management level, are more likely to implement further sustainable initiatives which could enhance the health, well-being and productivity of employees.

It can be argued that this objective of determining who is responsible within organisations for introducing sustainable initiatives, aswell as the Facilities Managers' opinion of their responsibility of employee productivity is the most important in achieving the aim of this study. Four that Facilities Managers strongly felt that high level staff were responsible for introducing sustainable initiatives within the workplace, and it had to be filtered down from the top. It was generally agreed that Facilities Managers should be driver behind it and recommendations should come from themselves as well as high level management, but ultimately the decisions were made at the top. The big issue on this theme, as well as regarding the future of sustainable FM, is the Facilities Managers view on responsibility of managing the sustainable initiatives once they have been implemented. In Kwawu and Elmualim (2011), it was found that the key driver of sustainability policies, which was legislation, had a direct impact on the responsibility of Facilities Managers. Yet in this study, the health, well-being and productivity of employees was the key driver and mentioned twice as much legislation, but the facilities managers view towards managing that, was that they had more important responsibilities. It was said that whilst it is easy to get involved with and it features highly within organisations, it doesn't feature highly within their day to day job. Although they promote it, with the pressures of what goes on, they have not got the time to dedicate to implementing sustainability policies, as a lot of the time they are 'firefighting' and dealing with 'quick fix projects'. So, although the health, well being and productivity is acknowledged as a key driver and it can result in significant financial benefits for the organisations, if it is not a key responsibility or does not feature in their day to day job, it is unlikely that it will improve.

It is generally agreed that sustainability should not stop on the completion of projects, whether it be new build or refurbishing an existing building to a green building standard, and should be continued through to occupation. Introducing sustainability policies are the first steps for organisations for when they are trying to deliver on their environmental commitments, as well as introduce sustainable practices. However, to ensure it is successfully implemented and does not fail, it is recommended that organisations have an Environmental Management System (EMS) in place. An EMS is a system and database which integrates procedures and process for training of personnel, monitoring, summarising, and reporting of specialised environmental performance information to the internal and external stakeholders. The most widely used international standards for the EMS is ISO:4001 and through a successful implementation of the EMS system, it will help to encourage organisational environment improvement as well develop a wider understanding of environmental issues. As a result of implementing this system, this may help to combat the challenges which the interviewees faced of successfully implementing their policies, as well as people taking it seriously.

Recommendations for change and improvement of sustainable FM is that staff training and development is essential for a clear understanding on how sustainable FM can be strategically applied to an organisations business strategy, and the impact. It can have on the core and non-core business objectives of an organisation. To be able to effectively manage green buildings and ensure it performs as intended over course the buildings lifecycle, it is imperative that Facilities Managers have the knowledge, training and capability on how to do so. This approach was hugely successful for an organisation which participated in the study, who said that the sustainability training course 'opened their eyes' and 'made them think about things they wouldn't normally think about'. The knowledge and skill set of Facilities Managers was one of the main barriers gathered from the literature review as well as this research study. Therefore, for Facilities Managers to be able to effectively introduce and manage sustainable initiatives which enhance the health, well-being and productivity of employees, this should be addressed.

The main research limitation for this study was undoubtedly the time scale which was available to gather primary data from research participants. The time constraints of the study was the rationale behind the selection of the cross- sectional design, as there was insufficient time available for a longitudinal study. Although the results and primary data received from the cases and interviewees who participated where extremely effective and valuable, the results of a longitudinal study may be more beneficial. The research was also limited by the number of organisations willing to participate in the study by allowing access into their organisation, which is not uncommon in case study research (Creswell, 2013). The results would have been more beneficial to the study if an equal amount of small, medium and large sized organisations were able to participate, as well as an equal amount of in house Facilities Managers and FM Consultants. Attempts to overcome these limitations can pave the further research endeavours.

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GREEN BUILDING CONSTRUCTION PROJECTS IN SINGAPORE: COST PREMIUMS AND COST PERFORMANCE

Ming Shan[1], Bon-Gang Hwang[1], Lei Zhu[2] and Xinyi Cheong[1]

[1]Department of Building, National University of Singapore, 4 Architecture Drive, Singapore

[2]Department of Construction and Real Estate, Southeast University, 2 Sipailou, Nanjing, China

ABSTRACT

While there has been a wealth of research on the life cycle cost of green buildings, few of them addressed the cost management performance of green building construction projects. As a result, this study aims to investigate the cost premiums and the cost performance of such projects in Singapore, which is an active global leader for green buildings, and to come up with feasible solutions that can help reduce the cost premiums and improve the cost performance. To achieve these goals, an extensive literature review and a questionnaire survey were conducted. Data collected from 121 green building construction projects showed that the green cost premiums in Singapore ranged from 5% to 10%, with different project type and size being significant factors affecting the premiums. It also reported that the majority of green building construction projects exhibited poor cost performances, with cost overruns ranging from 4.5% to 7%. Lastly, six strategic solutions that can reduce the cost premiums and improve the cost performance were proposed. This study contributes to the body of knowledge by adding the literature and findings in the context of the cost premiums and cost performance of green building construction projects. Furthermore, it can provide the industry professionals with an in-depth understanding of green cost premiums and performance as well as the responding control solutions, helping them make better decisions on cost-related management approaches from the beginning of such projects.

Keywords: *Cost Management; Cost Performance; Cost Premiums; Green Building; Green Construction.*

1. INTRODUCTION

Over the past two decades, green buildings are becoming increasingly popular in a large number of countries around the world (Zuo & Zhao, 2014). According to Dodge Data & Analytics (2016), green buildings would continue to expand worldwide in the coming decades, particularly in developed countries like the United States, the United Kingdom, Canada, Germany and Singapore. Such a remarkable green expansion is mainly because green buildings can offer substantial environmental benefits. According to the United Nations Environment Programme (UNEP, 2009), a 30 to 80 percent cut in energy consumption of buildings is attainable if the right green technologies are used. Additionally, the World Green Building Council (WorldGBC, 2014) reported that the design of an office building could also impact the health, well-being, and productivity of its occupants.

In spite of the benefits of green buildings and the various efforts being made to promote a sustainable built environment, numerous practitioners in the construction industry are still somewhat sceptical about the financial benefits that green buildings can deliver. Particularly, many industry professionals have the perception that the design and construction costs of green buildings are 10 to 20 percent higher than those of traditional buildings (WorldGBC, 2013). The higher costs associated with "going green," namely the green cost premiums, are the one of the most common reasons hindering the widespread development of green buildings (Dodge Data & Analytics, 2016; Robichaud & Anantatmula, 2011).

*Corresponding Author: E-mail – bdgsm@nus.edu.sg

As a result, the objectives of this paper are: (1) to investigate the cost premiums of green building projects and the significant reasons for them; (2) to compare the cost performance between green and traditional building projects; and (3) to examine plausible solutions that can improve the cost performance of green building projects, eventually cutting off their cost premiums. This study will contribute to the green building body of knowledge by adding to discussions of cost premiums and the cost performance of green building projects. Furthermore, the findings from this study can assist industry practitioners in making better cost-related decisions right at the beginning of green building projects.

2. BACKGROUND

2.1. GREEN BUILDINGS AND THE RATIONALES

There are various definitions of the term 'green building' and many varied perspectives of what constitutes a green building. According to Glavinich (2008), the term green building is defined in The United States as a building that provides the specified building performance requirements while minimizing disturbance to and improving the functioning of local, regional and global ecosystems both during and after its construction and specified service life. In Singapore, a building is considered green if it has met the requirements under the Green Mark Scheme, which requires the building to be both energy and water efficient, be environmentally sustainable, have a minimum indoor environment quality and possess green features (BCA, 2009). Despite having multiple definitions, a green building essentially means a building that is energy and resource efficient and has minimal disruptions to the environment (Zuo & Zhao, 2014).

Green buildings have environmental, economic benefits. Green buildings first benefit the environment. Globally, buildings are responsible for 40 percent of annual energy consumption (UNEP, 2011). Moreover, buildings were responsible for about one-third of greenhouse gas (GHG) emissions in the world (WorldGBC, 2013). Therefore, the building sector could lead to a great and efficient reduction of GHG emission if appropriate green technologies, materials, and construction methods were used (Wu et al., 2014). Green buildings also bring economic benefits in terms of energy and water savings and lower operating costs. Fowler and Rauch (2007) reported that green buildings could consume 26 percent less energy and saved 13 percent of maintenance costs when compared to traditional commercial buildings. Green buildings not only lead to energy savings but also provide social benefits, such as the increase in occupants' satisfaction, and positive impacts on occupants' health and productivity. Singh et al. (2010) and Thatcher and Milner (2014) investigated the effects of a green office building on the perceived health and productivity of occupants and found that the green building significantly contributed to an increase in the self-reported productivity and physical well-being of employees. Barrett et al. (2013) carried out a questionnaire with 751 students from 34 various classrooms in seven different schools in the United Kingdom and found that 'green' classrooms have a significantly different impact on a student's study progress.

2.2. COST PREMIUMS OF GREEN BUILDING PROJECTS

The development of green buildings is often greatly discouraged by the perceived higher costs, commonly termed green cost premiums, compared with traditional non-green buildings (Dodge Data & Analytics, 2016; Chandramohan *et al.,* 2012). Currently, there is no standardized definition for green cost premiums and no clear methodology to describe the components and to estimate green cost premiums (Dwaikat & Ali, 2016; Nalewaik &Venters; 2010; Kubba, 2010). Kats (2010) defined green cost premiums as the differential cost between a green and traditional version of the same building. Houghton *et al.* (2009) defined green cost premiums as the additional design and construction costs associated with specific green components. In terms of the general costs of a typical building, which consist of capital costs, operation costs, as well as repair and maintenance costs (Hendrickson & Au, 1989), Furr *et al.* (2009) stated that the additional capital costs of green building features are commonly termed green premium by the industry. In light of the above review, this study defines green cost premiums as the additional capital costs caused by green building features.

Design and construction costs are perceived as contributing to the green cost premiums (Johnson, 2000; Chandramohan *et al.,* 2012). Green building projects generally have more complex designs as compared with traditional building projects. In order to achieve sustainability, green building projects generally require the use of special specifications, materials, construction methods, and building practices (Lam *et al.*, 2010;

Robichaud & Anantatmula, 2011). Moreover, the productivity of the design and construction of green building projects is currently lower than that of traditional projects because practitioners still need time to learn and become proficient in these technologies. Furthermore, unfamiliarity with green technologies and technical difficulties during the construction process can not only affect the project schedule, but can also lead to cost increases through rework (Hwang *et al.*, 2009; Hwang *et al.,* 2015; Tagaza &Wilson, 2004).

Researchers in several countries such as The United States, The United Kingdom and Australia have started investigating green cost premiums (Dwaikat & Ali, 2016). Kats (2010) conducted a large-scale study based on extensive financial and technical analyses of more than 150 green buildings in the United States and ten other countries. The results of the study showed that green buildings cost roughly 2 percent more to build than traditional buildings. Moreover, Kim *et al.* (2014) concluded that the green cost premiums for residential project development in Los Angeles were 10.77 percent. In addition, Houghton *et al.* (2009) found that the green cost premiums for healthcare buildings in the United States were around five percent. In the United Kingdom, Building Research Establishment (BRE) and Cyril Sweett (2005) asserted that the green cost premium were up to 7 percent. In Australia, Langdon (2007) reported that the impact on the construction cost ranged from 3 percent to 5 percent for a five-star rating. Dodge Data & Analytics (2016) also conducted a study on the challenges of green buildings and identified that higher perceived first costs were one of the top three challenges in nearly all the 13 surveyed countries.

The building industry of Singapore recognizes the importance of sustainable construction to create a high-quality living environment for all. The Building and Construction Authority of Singapore (BCA) has launched three editions of its Green Building Masterplan from 2006 to aid in the greening of Singapore's current and future buildings (BCA, 2014). Singapore is now in the midst of a robust increase in the level of green activity (Dodge Data & Analytics, 2016). Despite the rapid development, green buildings in Singapore encountered a series of significant obstacles. One of the major obstacles is the high premium cost associated with green building construction (Hwang & Tan, 2012). Furthermore, the costly green building practices were also recognized as a major obstacle to the green development in Singapore (Chan *et al.,* 2009). However, compared to other leading countries who has conducted extensive research on green cost premium (Houghton *et al.,* 2009; Langdon, 2007), Singapore lacks knowledge and data on green cost premiums. Therefore, this paper investigated the cost premium situation in green buildings in Singapore, aiming to bridge the knowledge gap.

2.3. COST PERFORMANCE OF GREEN BUILDING PROJECTS

Cost performance indicates how well costs are kept under control, namely over budget or under budget. A few studies have been conducted to examine the cost performance of green building construction projects. For instance, Chandramohan *et al.* (2012) assessed the cost overruns of green building projects; Son *et al.* (2015) identified important factors that may affect cost performance of green building projects; Kang *et al.* (2013) compared the impact of pre-project planning on cost performance between green and traditional building projects. Additionally, Robichaud and Anantatmula (2011) tried to improve the chances of delivering the project within acceptable costs by suggesting some construction management adjustments to traditional project management practices. Nevertheless, generally there is still a lack of studies investigating the actual cost performance of green building projects.

A few studies have been conducted on the cost performance of traditional building projects as compared with green building projects. Particularly, two indicators widely used for measuring the general project cost performance are project cost growth and project budget factor, which were proposed by the Construction Industry Institute, The University of Texas at Austin (Thomas *et al.,* 2002). Project cost growth was calculated by dividing the difference between 'actual total project cost' and 'initial predicted project cost' using 'initial predicted project cost.' Project budget factor was calculated by dividing the 'actual total project cost' using the sum of 'initial predicted project cost' and 'approved changes.' Using these two indicators, Thomas *et al.* (2002) conducted a survey on 617 U.S. domestic and international traditional construction projects to investigate the impacts of two delivery systems: design-build (DB) and design-bid-build (DBB), on project cost performance. The results showed that the project cost growths for DB and DBB projects were -0.041 and -0.030, respectively, from the owners' perspective; the project cost growths for DB and DBB projects were 0.038 and 0.056, respectively, from the contractors' perspective. The results indicated that the cost performance of the U.S. traditional construction projects was below or slightly above budget. The project budget factor for DB and DBB projects were 0.966 and 0.948, respectively, from the contractors' perspective, indicating that the changes generally contributed to a 3 to 5 percent cost increase. In light of the above, this study used the project cost growth to investigate the cost performance of green building projects in Singapore. This study did not use the project budget factor because valuing changes/variations is relatively challenging.

3. METHODOLOGY AND DATA PRESENTATION

This study first carried out an extensive literature review from multiple sources including government websites, reports from private institutions, and journal papers, to provide a better understanding of the current market situation of green building and the issues relating to cost premiums and cost performance of green building construction projects. Then a questionnaire was subsequently developed. The questionnaire was to: (1) capture the current perceptions of professionals on cost premiums and cost performance of green building projects, (2) identify the significant reasons for cost premiums, and (3) gauge the effectiveness of proposed solutions to reduce green cost premiums and improve cost performance. The collected data were analysed using the Statistic Package for Social Science (SPSS) statistical software.

The developed questionnaire consists of five sections. The first section provided a definition of green cost premiums. The second section included questions meant to profile the companies and respondents. In the third section of the questionnaire, the respondents were asked to indicate the cost premiums of green building projects by different project types and sizes. The fourth section of the questionnaire requested the respondents to rate the significance of the reasons for the difference in the cost premiums between green and traditional building projects using a five-point scale (i.e., 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree). Lastly, the fifth section of the questionnaire asked respondents to rate the effectiveness of the solutions that may reduce the cost premiums of green buildings and improve their cost performance using another five-point scale (i.e., 1 = least efficient, 2 = somewhat efficient, 3 = neutral, 4 = efficient, and 5 = most efficient). Furthermore, post-survey interviews were carried out with two green building professionals who had at least three years of experience in the green building industry, especially in green building costs management, to validate the findings generated by the questionnaire.

The population of the questionnaire survey consisted of all the professionals who had BCA Green Mark certificate, members of the Singapore Institute of Surveyors and Valuers (SISV), and the BCA directory of registered contractors and licensed builders with at least three years of experience in the green building industry and specialized in green building cost performance. The questionnaires were randomly sent out to the professionals via emails. Thirty responses were received finally. Although the sample size was relatively small, statistical analysis could still be performed because the central limit theorem holds true when the sample size is no less than 30, which is a generally accepted rule (Ott & Longnecker, 2015). The profiles of the respondents, companies, and projects are provided in Table 1.

Table 1: Backgrounds of the Respondents and their Companies

Profile	Frequency	Percentage
Company (total = 30)		
Type		
Architecture	2	7
Quantity surveying	5	17
Contractor	23	76
Total	30	100
Respondent (total = 30)		
Job title		
Project Manager	8	27
Quantity Surveyor	5	17
Contractor	17	56
Total	30	100
Years of experience in green building construction		
Less than one year	9	30
1 to 2 years	0	0
2 to 3 years	5	17

Profile	Frequency	Percentage
3 to 4 years	6	20
More than four years	10	33
Total	30	100
Project		
Traditional		
Commercial	124	51
Offices	20	8
Residential	98	41
Total	242	100
Green		
Commercial	57	47
Offices	10	8
Residential	54	45
Total	121	100

As indicated in Table 1, the respondents consisted of project managers, quantity surveyors, and contractors from different types of companies such as architecture, quantity surveying, and contractor firms. Particularly, 70% of respondents had at least two years' experience in green building construction. Given the duration of a normal building project is around two years in Singapore, it can be inferred that most of the respondents have sufficient experiences regarding the problem of cost in green building projects and thus were able to provide reliable cost assessments and objective judgment. Additionally, as indicated in Table 1, a total of 242 and 121 traditional and green building projects were recorded from the questionnaire, respectively. The percentages of the three types of projects (i.e., office, commercial, and residential) in traditional and green building project were generally comparable, suggesting no bias would generate from the unequal distribution of projects.

A series of statistical tests were conducted to analyse the collected data. Specifically, one-way analysis of the variation (ANOVA) test was performed to test whether the project type and project size have significant effects on green cost premiums. Turkey post hoc (TPH) test was conducted subsequently further to analyse the proved differences. Furthermore, one sample t-test was conducted to check whether the identified reasons have significant effects on the premium differences between green and traditional projects, and to check whether the proposed solutions are effective.

4. RESULTS AND DISCUSSIONS

4.1. OVERALL PERCEPTIONS ON GREEN COST PREMIUMS

According to the results of the questionnaire, a total of 43% of the respondents perceived green cost premiums to be 5% ~ 10%, followed by 34% and 23% of the respondents who perceived green cost premiums to be 10% ~ 15% and 0% ~ 5%, respectively. None of the respondents perceived green cost premiums to be above 15%. This result was confirmed by the professionals attending post-survey interviews, and was also in line with the argument made by Houghton *et al.* (2009) that green cost premiums were getting lower as a result of decreasing capital cost over time. Furthermore, according to a report from WorldGBC (2013), building professionals - both with experience and without any experience in green projects - tended to perceive green cost premiums to be up to 13% and 18%, respectively, which was not significantly different from the analysis results of this study.

4.2. ACTUAL COST PREMIUMS OF GREEN BUILDING PROJECTS

The cost premiums for green projects by project size (i.e., less than S$5 million, S$5 million to less than S$50 million, S$50 million and above) and type (i.e., green commercial, office, and residential buildings) are summarized in Table 2. This result was derived from the respondents' inputs, which were based on green building projects in which they had been involved. As shown in Table 2, there were indeed cost premiums for going green, generally ranging from 0% to less than 15%, regardless of the project type and size. This result was consistent with the overall perception on the green cost premiums presented in the previous section.

Table 2: Cost Premiums of Green Building Projects by Project Type and Size

Project size (S$ · million)	Capital cost premiums (CCP)	No. of green commercial	No. of green office	No. of green residential
Less than 5 (small)	0% =< CCP < 5%	1	2	0
	5% =< CCP < 10%	9	1	1
	10% =< CCP < 15%	0	0	4
	15% =< CCP < 20%	0	0	0
	20%=< CCP	0	0	0
5 to 50 (medium)	0% =< CCP < 5%	12	0	0
	5% =< CCP < 10%	9	4	2
	10% =< CCP < 15%	9	0	3
	15% =< CCP < 20%	2	0	2
	20%=< CCP	0	0	0
50 and above (large)	0% =< CCP < 5%	11	3	32
	5% =< CCP < 10%	4	0	5
	10% =< CCP < 15%	0	0	5
	15% =< CCP < 20%	0	0	0
	20%=< CCP	0	0	0

4.3. ACTUAL COST PREMIUMS BY PROJECT TYPE

The mean cost premiums of green building projects by project size and type are shown in Table 3. The overall mean of green cost premiums ranged from 2.5% to 12.5%. This result was comparable with the conclusion drawn by Kansal and Kadambari (2010) that the initial costs of a green building were 7.5% more than those of the ordinary building. Additionally, it is obvious that green residential has the highest cost premiums, followed by green commercial and green offices for three different size classifications. To test whether the project type has a significant effect on green cost premiums, one-way analysis of the variation (ANOVA) test was performed. Because the one-way ANOVA test does not show which specific building types significantly differ, the Tukey post hoc (TPH) test was subsequently performed to further analyse the difference. Table 4 summarizes the results.

Table 3: Mean Cost Premiums of Green Building Projects by Project Size and Type

Project size (S$ · million)	Mean of green cost premiums		
	Commercial	Office	Residential
Less than 5 (small)	7.0%	4.2%	11.5%
5 to 50 (medium)	7.7%	7.5%	12.5%
50 and above (large)	3.8%	2.5%	4.3%

Table 4: ANOVA and TPH Results by Project Type

Project size (S$ · million)	p-value (ANOVA)	p-value (Tukey Post Hoc)	
Less than 5 (small)	0.000	C vs R	0.002
		R vs O	0.000
		C vs O	0.110
5 to 50 (medium)	0.045	C vs R	0.038
		R vs O	0.197
		C vs O	0.998
50 and above (large)	0.601	No difference	

The p-values from the ANOVA test for projects under S$50 million were smaller than 0.05, indicating the building type had a significant effect on the mean of green cost premiums when the project size was small or medium. When the project size was large, the building type did not have a statistically significant effect on the mean of green cost premiums. According to the results from the TPH test, the means of the cost premiums were statistically different between commercial and residential building projects, and between office and residential building projects when the project size was small. As for medium sized projects, only commercial and residential building projects had statistically different cost premiums.

4.4. ACTUAL COST PREMIUMS BY PROJECT SIZE

From the perspective of project size, large-scale projects have the lowest means of green cost premiums for all three building types, followed by small- and medium-scale projects, as shown in Table 3. One possible explanation for this result is that respondents involved in large-scale projects were mainly professionals with a good deal of experience in green building projects and thus were able to efficiently utilize green products without increasing overall design and construction costs (Malin, 2000). Also, respondents with sufficient experience in green building were more likely to adopt the right strategies, lowering green cost premiums accordingly (Bordass, 2000). To test whether the project size has a significant effect on green cost premiums, ANOVA and TPH tests were performed again. As indicated in Table 5, the p-values from the ANOVA test for three building types were all smaller than 0.05, indicating the project size had a significant effect on the mean of green cost premiums regardless of the building type. Further analysis based on the p-value from the TPH test indicated that green cost premiums were statistically different for medium- and large-scale projects in all three building types, whereas cost premiums were statistically different for small- and large-scale projects only in residential projects.

Table 5: ANOVA and TPH Results by Project Size

Project Type	p-value (ANOVA)	p-value (Tukey Post Hoc)	
Commercial projects	0.010	Small vs Medium	0.888
		Medium vs Large	0.008
		Small vs Large	0.124
Office projects	0.010	Small vs Medium	0.059
		Medium vs Large	0.009
		Small vs Large	0.428
Residential projects	0.000	Small vs Medium	0.875
		Medium vs Large	0.000
		Small vs Large	0.000

4.5. REASONS FOR DIFFERENT COST PREMIUMS BETWEEN GREEN AND TRADITIONAL BUILDING PROJECTS

One-sample t-test was performed to check whether each of the reasons had a significant effect on the difference in cost premiums between green and traditional building projects. Because a five-point scale was used, the test value was set as 3 which is the middle value of the scale. Table 6 summarizes the test results as well as the ranking of the reasons. It can be found that except R1 and R6, all the rest reasons had significant effect on the difference as their means were statistically higher or equal to the test value 3. "High cost of green technologies and materials" was the top reason for the difference in cost premiums between green and traditional building projects. This is because green materials and technologies are normally more costly than traditional materials and technologies (Hwang et al., 2016). "High research and development costs for green building products and systems" was ranked second. This might be due to the fact that new green products and systems usually require more efforts in testing and code approvals, which leads to an increase in research and development costs (Malin, 2000). "Lack of required green expertise and information," which ranked third, could also lead to an unnecessary increase in cost premiums. This is because, without sufficient green building expertise, the professionals will inevitably have difficulty in using green construction method properly, which may cause reworks as a result and finally leading to an increase in the capital cost of the green building projects (Architecture Week, 2001).

Table 6: Ranking of the Reasons for the Difference in Cost Premiums

SN	Reasons	p-value	Mean	Rank
R1	Higher consultant and designer fees	0.022	2.60	6
R2	Lack of required green expertise and information	0.315	3.10	3
R3	Difficulty in getting green services from contractors and subcontractors	0.5000	3.00	5
R4	Difficulty in getting green resources e.g. materials, technologies etc.	0.444	3.03	4
R5	High cost of green technologies and materials	0.000	3.70	1
R6	Lack of Government incentives/subsidies for green building projects	0.034	2.57	7
R7	Higher research and development costs for green building products, systems, technologies etc.	0.221	3.13	2

4.6. COMPARISON OF COST PERFORMANCE BETWEEN TRADITIONAL AND GREEN BUILDING PROJECTS

Table 7 summarizes the cost performances of traditional and green building projects by project type. The negative and positive percentages indicate an "under budget" and "over budget" cost performance of projects, respectively. It can be found from Table 7 that, regardless of project types, green projects generally had a cost overrun, whereas traditional projects were generally under budget. One primary reason for such results might be professionals' unfamiliarity and insufficient expertise in green building projects compared with traditional projects (Hwang *et al.,* 2016). Another possible reason for the cost overrun of green building projects was that they were more likely to be delayed than traditional projects. Hwang and Leong (2013) found that 33.33% of green projects encountered a delay, as opposed to only 17.39% for traditional projects.

Table 7: Cost Performances of Traditional and Green Building Projects

Cost Growth (CG)	No. of Commercial Projects		No. of Offices Projects		No. of Residential Projects	
	Traditional	Green	Traditional	Green	Traditional	Green
-10% <= CG < -5%	10	0	7	0	30	0
-5% <= CG < 0%	60	6	4	0	42	0
0% <= CG < 5%	54	22	7	1	21	32
5% <= CG < 10%	0	29	2	9	5	22
Total	124	57	20	10	98	54

5. SOLUTIONS FOR COST PREMIUMS REDUCTION AND COST PERFORMANCE IMPROVEMENT

Table 8 presented the assessment results of the solutions that may reduce cost premiums and improve cost performance of green building projects. To determine the effectiveness of the solutions, one-sample t-test was performed. Because a five-point scale was used, the test value was set as 3, namely the middle value of the scale. It can be found from Table 8 that all the solutions were statistically effective as their assessments were statistically higher or equal to the test value 3. "Tax relief" was ranked as the most effective solution. It can bring economic benefits to businesses and individuals who have been using green products and systems and thereby make them stick to their choice of green (Bourgeois et al., 2010). "Availability of skilled and experienced project team" was ranked as the second most effective solution. Green building projects generally have a more complex design as compared with traditional building projects (Hwang et al., 2016). With a skilled and experienced project team, both lower cost premiums and better cost performance can be achieved because the right green design features and materials can be correctly and efficiently adopted during the design and construction period (Malin, 2000). Furthermore, if a project team has sufficient green building expertise, the cost performance of green buildings can be much improved because costs caused by unnecessary rework and changes can be avoided (Architecture Week, 2001). "Incentives/subsidies for green building projects" and "subsidies for green building professional and specialist courses from the government" were ranked third and fourth, respectively. From a practical standpoint, incentives from the government are extremely important for attracting and motivating hesitant building professionals to build green. Additionally, a good education on green products and systems can also be helpful as it can make industry practitioners more familiar with green products and systems (Nalewaik & Venters, 2010), thereby achieving cost premium reduction and cost performance improvement. These two solutions were also highly recommended by the professionals attending the post-survey interviews.

Table 8: Ranking of the Solutions to Reduce Cost Premiums of Green Buildings

Code	Solutions to reduce cost premiums	p-value	Mean	Rank
S1	Government to provide incentives/subsidies for green building projects	0.000	3.70	3
S2	Low interest loans	0.242	2.83	7
S3	Financial institutions to introduce lending schemes customized for green building projects	0.173	2.77	8
S4	Government to provide subsidies for research and development of green building products, systems and technologies	0.109	3.33	5
S5	Tax relief for developers and contractors for use of green building products, systems and technologies	0.000	3.83	1
S6	Availability of skilled and experienced project team and contractors	0.000	3.80	2
S7	Government to provide green building educational courses for key building players so as to flatten the learning curve of green construction	0.116	3.30	6
S8	Government to provide subsidies for green building professional and specialist courses	0.038	3.47	4

6. CONCLUSIONS AND RECOMMENDATIONS

Green buildings are becoming increasingly popular worldwide; however, the delivery of green buildings is still hindered by the higher cost associated with "going green." As a result, this study aimed to investigate the current cost premiums of green building projects and identify the significant reasons for these cost premiums. In addition, the cost performance of green and traditional building projects was compared. Some plausible solutions that can reduce cost premiums and improve the cost performance were also proposed.

The first finding from this study was that the majority of the respondents perceived green cost premiums to be 5% ~ 10%, with green residential buildings having the highest cost premiums, followed by green commercial and green office buildings. Furthermore, it was proven that "project type" and "project size" were statistically significant variables affecting cost premiums. This study also identified that "high cost of green technologies and materials," "higher research and development costs for green building products, systems, technologies, etc.," and "lack of required green expertise and information" were the top three reasons for the cost premiums of green building projects. As for current cost performance, it was concluded that green building projects were generally over budget (4.5% ~ 7%), which was worse than traditional building projects. Finally, "tax relief" was identified as the most efficient solution that could have a significant impact on reducing cost premiums and improving the cost performance of green building projects.

Although the main objectives of this study were achieved, there are some limitations. First, caution should be given when the analysis results are interpreted and generalized because the sample size was relatively small. Second, the findings from this study were well interpreted in the context of Singapore, which may be different from the contexts of other countries. In spite of these limitations, the findings from this study are valuable. First, this study provides an exploratory investigation of cost premiums and cost performances of green building projects which can enhance practitioners and researchers' understanding in this regard. Second, the reasons and solutions investigated in this study can help the policy makers to come up with some measures that are more effective in reducing cost premiums and improving cost performance in green building projects.

Further studies can investigate green building projects performed in other countries in the sense of cost premiums and cost performance, and provide the results from comparisons of projects. In addition, because this study was focused on new green building projects, other kinds of green building projects, such as green retrofit or maintenance projects, can be studied further.

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HEALTH AND SAFETY (H&S) CHALLENGES CONFRONTED BY FOREIGN WORKERS IN THE MALAYSIAN CONSTRUCTION INDUSTRY: A BACKGROUND STUDY

Rafidah Ismail[1*], Roshani Palliyaguru[1], Gayani Karunasena[1] and Norfaridatul Akmaliah Othman[2]

[1]School of Architecture and Built Environment, Deakin University, Australia

[2]Faculty of Technology Management and Technopreneurship, University Technical Malaysia Melaka, Malaysia

ABSTRACT

Many scholars indicated that the occupational accidents rate for foreign workers is higher than for domestic workers in Malaysia. In 2015, a total of 140 Malaysia construction workers have suffered fatal injuries, consisting of 47 locals and 93 foreigners and these statistics show that the number of foreign workers who were killed was 2 times more than the number of local workers who died. This paper will therefore aim to promote a better understanding of the role of health and safety practices through identification of the challenges among foreign workers in Malaysian construction industry. The main study to which this paper relates actually adopts a mixed approach for empirical data collection. Whereas this paper is entirely based on secondary data collated through an extensive critical literature review. Findings of this paper provides a general overview of the health and safety challenges faced by foreign workers such as human-rights related problems, difficulty of applying working permit, communication barriers, compensation and insurance scheme, equal treatment, working environment and accommodation issues in Malaysian construction industry which has the potential to lead the relevant authorities such as policy makers and governmental officials in taking necessary steps to improve the safety practices among the local and foreign workers.

Keywords:*Foreign Workers; Health and Safety Challenges; Malaysian Construction Industry.*

1. INTRODUCTION

For over three decades, Malaysia has relied heavily on the use of foreign workers either legally or illegally in the manufacturing, construction, plantation, agricultural, services and domestic sector. The importation of foreign workers into Malaysia is a necessity when the country was facing an acute shortage of labour force. Hence, the number of foreign workers in Malaysia has increased from approximately 0.5 million in 1984 to 0.63 million in 1997, 2.4 million in 1998, 1.9 million in 2006, and then 2.1 million in 2009 (Abdul-Rahman *et al*., 2012).

Many cases had been reported that some of the foreign workers who arrived in Malaysia were unable to cope with new working environments in large scale projects because they do not have adequate training and even not specialized in their works; do not have enough construction experience; thus resulting in low productivity and poor quality of work (Marhani *et al*., 2012). Besides, the Malaysian construction companies also faced many problems when some of the foreign workers were absent during working hours and ran away after they arrived in Malaysia (Marhani *et al*., 2012). Apart from that, the social problems related with foreign workers have further aggravated the situation (Abdul-Rahman *et al*., 2012). Further, Wei and Yazdanifard (2015) claimed that most of the construction sites in Malaysia are dirty, tough and dangerous, with few of the recommended safety precautions being followed. Wei and Yazdanifard (2015) also noted that despite the

*Corresponding Author: E-mail – rbismail@deakin.edu.au

unpleasant and unsafe working environment, Malaysian foreign workers are not bother by this deficiency and are still willing to take these risky jobs that locals usually do not wish to do just to earn a living.

In 2015, a total of 140 Malaysian construction workers have suffered fatal injuries, consisting of 47 locals and 93 foreigners and this shows that the number of foreign workers who killed were 2 times more than the number of local workers (DOSH, 2016). Further, many scholars indicated that the rate of occupational accidents for foreign workers is higher than for domestic workers in countries such as US, UK, Australia, Japan, Singapore and Taiwan (Cheng & Wu, 2013). For example, according to the statistics of Taiwan's Bureau of Labor Insurance (2010), all-industry occupational accident rate per 1,000 workers in Taiwan was 4.493 in 2007 and the rate of occupational accidents per 1,000 foreign workers were 5.855. This figure is 1.32 times higher than all laborers and indicates a serious problem in foreign worker occupational safety.

Consequently, to avoid any occurrence of accidents in Malaysia, early safety implementation based on the Occupational Safety and Health Act 1994 (OSHA) was introduced by compelling employers to comply with the rules that were set to provide or send the foreign workers to attend training or courses to get safety information before start working on construction sites. Safety and Health Induction Course (SHIC) is an important basic course and must be attended by foreign workers before entering or start working on a construction site in Malaysia. The objective of this course is clear; which make workers realize the dangers on construction sites, ability to reduce the damage or injury to other workers, public or properties and to comply with the safety law and regulations (Teck *et al*., 2015; Salleh *et al*., 2012). Despite the fact that these are prevailing, accidents in the Malaysian construction industry are still prominent in the industry. Thus, the purpose of this paper is to promote a better understanding of the role of health and safety practices through identification of the challenges among foreign workers in the Malaysian construction industry.

As an initial step towards achieving the purpose, this paper aims to identify the main accidents and health-related problems faced by foreign workers in the construction industry. Ultimately, the findings of this study will provide a better understanding of health and safety practices and challenges among foreign workers in Malaysian construction industry which need to be addressed by relevant authorities such as policy makers and governmental officials in taking the necessary steps to improve the safety practices among foreign workers. This paper is based only on secondary data collated through an extensive critical literature review.

2. MALAYSIAN CONSTRUCTION INDUSTRY

The construction industry is a very important part in the economy of Malaysia. The industry is made up of many components includes thousands of contractors, workers, developers, client organizations (government and private), management, engineering, architectural, and surveying consultants, manufacturers, material suppliers, plant hirers. The government is an important player in the industry through its agencies: Ministry of Works, Public Works Department (PWD), Construction Industry Development Board (CIDB), Contractor Service Centre (PKK), Board of Engineers, Board of Architect and Board of Surveyors. All of these components play an important role in the growth and development of Malaysian construction industry (Kamal *et al.,* 2012). Since independence in 1957, the Malaysian construction industry has developed from a low-tech, labour intensive, craft-based industry to one that has a capacity to deliver advanced buildings and infrastructure, using highly mechanized production techniques seen in projects such as Kuala Lumpur's Twin Towers and Kuala Lumpur International Airport (Kamal & Flanagan, 2012).

Furthermore, Malaysian construction industry is one of the productive sectors which have contributed significantly to the Malaysian economy as a catalyst for the growth of other industries. Although it accounts for less than 5% of Gross Domestic Product (GDP), the industry is an essential growth enabler because of its extensive linkages with the rest of the economy, for example, the manufacturing, professional services, financial services, education and other industries (Marhani *et al*., 2012).

Nevertheless, during the last few decades, the move of Malaysian workforce to jobs with better economic opportunities saw certain sectors such as construction, plantations, forestry and certain services experiencing labour "shortages". It means that an insufficient numbers of workers reacting to the wage levels and conditions of employment offered by employers in the respective industries or sectors. This resulted in labour market vacancies being increasingly filled by foreign workers (Marhani *et al*., 2012). Besides, Abdul-Rahman *et al*., (2012) indicated that the Malaysian construction industry provides employment opportunities for 800,000 workers, representing 8% of the total workforce; 69% of these are foreign workers.

Therefore, according to Pillai (1999), Malaysian construction sector has become the most significant dependence on foreign worker among Asian country. Foreign construction workers (unskilled and semi-skilled migrant workers) in Malaysia were from adjacent regions; Indonesia is the leading source of labour, followed by Myanmar, Pakistan, India, and the Philippines. The quality of foreign workers in term of working skills is the weakness of the list in exchange for cheaper manpower in the industry. According to Han *et al*., (2008), most of the foreign workers arriving in Malaysia are unskilled, which has reduced the productivity and the quality control within the construction industry. Moreover, an unskilled foreign worker will contribute to a significant amount of safety related issues, due to the lack of safety knowledge and safety awareness.

In addition, the construction workers mostly work in small firms or trade sub-contractors. They work longer hours but their salary is around the average wage of other industries. In contrast to developed countries such as Japan, Singapore, South Korea, Australia or the United Kingdom (UK), there are signs of alarming gaps between skills of the work force in the Malaysia and those abroad. In these countries, more pre-fabricated construction is practiced resulting in unskilled workers becoming more marginal as employers increasingly employ only trained and skilled workers to work. On the contrary, the Malaysian construction workforce, both local and foreign workers tends to have very little skills, qualifications and training (CIMP, 2010; Jaafar *et al*., 2007).

In conjunction with that, many Malaysian are no longer willing to perform jobs in construction because they considered it as 3D's (dirty, difficult, and dangerous), hence contributed to dependency on the foreign workforce. They are not interested in working in rough natured work on sites, which needs more physical strength compared to working in air conditioned office. Furthermore, they are too choosy when making job decisions and believe that better qualifications will give better jobs (Marhani *et al*., 2012).

3. OVERVIEW OF HEALTH AND SAFETY IN THE MALAYSIAN CONSTRUCTION INDUSTRY

3.1. HEALTH AND SAFETY RULES AND REGULATIONS PREVAILING TOWARDS FOREIGN WORKERS

Safety is one of the most concerned elements in the workplace for the sky-high fatality status around the globe. In most organizations, especially high risk industries, safety issues in workplace are the main priority to be tackled. Today, construction industry is regarded as one of the least unsafe industrial sectors worldwide (Abudayyeh *et al*., 2006; Brunette, 2004; Mohamed, 1999). According to International Labour Organization (ILO) (2003), there are at least 60,000 people fatally injured in Switzerland construction industry each year and there are many more suffer serious injuries and ill-health. This number could represent only less than 20 per cent of actual construction injuries reported (ILO, 2003). Locally, Department of Occupational Safety and Health Malaysia (DOSH), Ministry of Human Resources has recorded a total of 763 cases of accidents from 2007 to 2012 in Malaysia's construction industry and 422 or 55% from the number was fatal accidents (DOSH, 2014).

Thus, identification of causes and effects of accidents is an important prevention strategy to reduce the growing number of injuries and fatalities among workers. According to Sawacha *et al*., (1999), the occurrence of accidents was much related to the lack of competency skills and knowledge of the worker to perform safely in the workplace. Whereas other researchers reported that unsafe worker behaviour and misperception of safety responsibilities among workers is often led to unsafe acts on the workplace which causes accidents (Sacks *et al*., 2013; Othman *et al*., 2012). It should be noted that safety knowledge and awareness and safe work behaviour are inter-related. According to Musonda and Smallwoord (2008), health and safety awareness is an antecedent of displays of behaviour, with accidents and incidents being the consequences of behaviour in the industry. Therefore, to reduce the occurrence of accidents in workplace, it is essential to improve the safety knowledge and awareness of the workers which would later result improvement in the safety behaviour of the workers. To improve the workers safety knowledge and awareness, safety training has been seen as an important effort that should be provided to the workers (Teck *et al*., 2015).

Hence, according to Salleh *et al*., (2012) shows that to avoid any occurrence of accident in Malaysia, early safety implementation based on the Occupational Safety and Health Act 1994 (OSHA) was introduced by compelling employer to comply with the rules that was set to provide or send the local and foreign workers to attend training or courses to get safety information before starting work on the construction site. Safety and Health Induction Course (SHIC) is an important basic course and must be attended by local and foreign workers before entering or start working on a construction site in Malaysia. The objective of this course is clear; to create an awareness among workers on the risks in construction sites, to reduce damage or injury to other workers, public or properties and to comply with the safety laws and regulations (Teck *et al*., 2015; Salleh *et al*., 2012).

In addition, by referring to the standardized materials (presentation slides, safety induction books and safety guidelines for construction workers) as provided by CIDB, the topics that cover during SHIC are OSHA 1994, housekeeping and cleanliness, fire prevention, hazard from electric, transportation and mobile plant, excavation, roof work, working on live roads, chemical hazards, working at height and personnel protective equipment. Furthermore, the immigrant workers need to undergone a special course conducted under the supervision of Ministry of Human Resources (MOHR) known as Induction Course for Foreign Workers working in Malaysia (MOHR, 2006). Some of the contents within the induction course include: (1) The Communication Proficiency - 30 hours, (2) Malaysian Culture - 10 hours and (3) Awareness of Malaysian Laws - 20 hours.

3.2. Foreign Workers in Malaysia

The beginning of foreign workers import started in the 1970s through the Malaysian government's New Economic Policy, which welcomes the labour shortage mainly that in the plantation sector from India (Ajis *et al*., 2010; Narayanan & Lai, 2005). Hence, proportion of Malaysian foreign workers in the overall workforce increased from 1:10 in 1995 to 1:18 in 1997. According to 8th Malaysian Plan, 2001 (as cited in Mustapa, 2014) it then recovered to 1:13 in 2000. As of 2005, 63,538 foreign workers were registered in Malaysia. In addition, another 244,242 workers are waiting for working permits (CIDB, 2006). Table 1 shows the distribution of foreign workers from 2006 until 2010 by sector in Malaysia.

Table 1: Distribution of Foreign Workers (Source: Department of Statistics, 2010)

Sector	2006	2007	2008	2009	2010
Manufacturing	628,576	766,451	737,523	355,710	539,579
Plantation	343,373	343,373	361,977	205,333	264,284
Construction	272,730	298,422	285,845	204,237	187,743
Agriculture	162,338	162,338	220,528	116,324	150,823
Services	305,393	293,771	264,591	206,863	247,051
Total	1,913,613	2,065,558	2,085,613	1,222,064	1,516,111

Table 1 show that manufacturing employs the largest percentage of immigrant workers, followed by the plantation sector. Construction and services sectors come third. Although the construction industry is smaller in terms of GDP contribution than both the manufacturing and plantation sectors, it is still a favoured sector for immigrants due to its nature. Furthermore, Table 2 shows the distribution of the approved immigrant construction workers by nationality from 2006 until 2010 in Malaysia.

Table 2: Distribution of the Approved Immigrant Construction Workers by Nationality (Source: Department of Statistics, 2010)

Nationalities	2006	2007	2008	2009	2010
Indonesia	219,880	208,920	183,961	172,329	151,333
Bangladesh	11,447	47,379	61,569	2,638	3,036
Thailand	1,245	1,402	1,613	781	463
Philippines	1,757	1,828	2,135	671	3,335
Pakistan	4,131	4,475	5,638	7,089	6,217
Myanmar	14,428	14,491	14,007	11,691	12,221
Nepal	4,389	4,678	3,704	3,078	3,050
Vietnam	5,893	5,090	3,613	226	1,965
Other	9,560	10,159	9,605	5,734	6,123

There seems to be an incremental increase in the amount of immigrant employment yearly. There seems to be an increasing pattern largely from the neighboring countries with similar backgrounds, such as language and culture. Indonesia continues to be the largest supplier for human capital followed by Bangladesh. In addition, according to Anglioinfo (2015), the Malaysian construction sector employs approximately 9 percent of their total workforce from Indonesia and other member nations of the Association of Southeast Asia Nations (ASEAN). In 2017, there were 1.78 million foreign workers in Malaysia as of June 30 and the majority comprising Indonesians, Nepalis and Bangladeshis. According to the home ministry's statistics, there were 728,870 Indonesians working in the country, followed by Nepalis (405,898) and Bangladeshis (221,089). There were also 127,705 Myanmar nationals, 114,455 from India and 59,281 Pakistanis. The remaining comprised Filipinos (56,153), Vietnamese (29,039), Chinese (15,399), Thai nationals (12,603), Sri Lankans (5,964), Cambodians (5,103) and Laos nationals (39).

3.3. TYPES OF ACCIDENTS

The construction industry is a very important part in the economy of Malaysia. However, the average five-year fatality rate for this industry is 99 employees each year (from 2011 to 2015). The fatality rate per 100,000 construction workers in 2015 is 10.94, higher than the average mortality rate for five years (2011- 2015) of 8.17. The trend of fatal injury in construction workers has risen since 2012, and 140 construction workers have died in 2015, the highest record since 2001 and in the 21st century (DOSH, 2016).

Furthermore, according to DOSH (2016) the five-year average (from 1999 to 2003) number of injured workers in all industries was 898, while the average five years from 2011 to 2015 was 639. The five-year average for the fatal of all industry workers showed a 28.8% decline. Five years average (from 1999 to 2003) number of workers injured in the construction industry was 115, while the average five years from 2011 to 2015 was 99. The five-year average for the fatal injuries of construction industry workers showed a decrease, but at a lower rate of 13.9%. In 1999, the construction industry accounted for 14.5% of the total number of deaths and injuries in all industries, and the percentage of this contribution increased to 21% by 2015. This demonstrated that 1 out of 5 job deaths occurred on construction sites. Figure 1indicates the number of fatal injuries in Malaysia construction industry from 1999 – 2015.

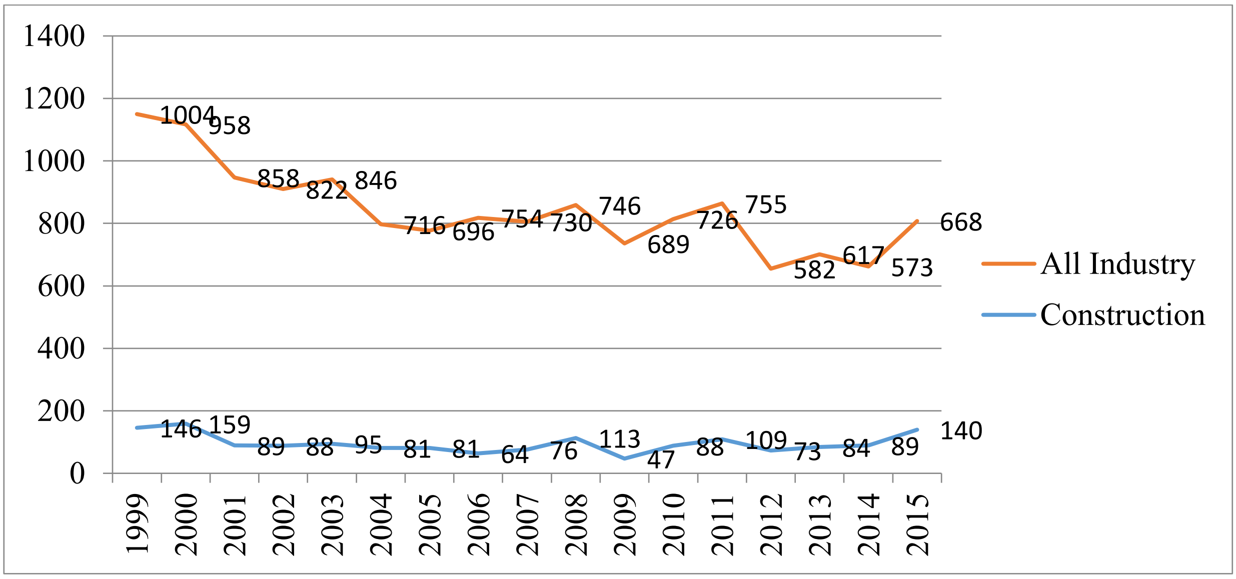

Figure 1: Numbers of Fatal Injuries among Construction Workers (Source: DOSH, 2016)

The most common types of accident are falls, stepping on, striking against or being struck by objects and etc, which happens when moving construction equipment strikes or runs over workers (Chong and Low, 2014). Falls are a critical cause of accidents with an annual average of 1042 cases in Malaysia (Chong and Low, 2014). In addition, statistics by DOSH (2016) indicated that main fatal injuries happened to the Malaysian foreign workers were fall from height, followed by stepping on, striking or being struck by objects.

Previous studies in other countries such as U.S has also pointed out that falls were the most common type of accident (Huang & Hinze, 2003). According to the Occupational Injury and Illness Classification Manual, falls can be grouped into 11 categories such as falls from stairs or steps; falls through existing floor openings; falls from ladders; falls through roof surfaces; falls from roof edges; falls from scaffolding or staging; falls from building girders or other structural steel; falls while jumping to a lower level; falls through existing openings; falls from floors, docks or ground level; and other no classified falls to lower levels (U.S. Department of Labor, 2012).

Furthermore, Yilmaz (2015) stated that the risk of possible accidents in construction sites depend on five different reasons; falling from height, falling objects and being hit by objects, machinery and crane accidents, electric shock, and explosion. For example according to SOCSO (2009) stated that causes of accidents in the Malaysian construction industry such as by incorrect use or poor maintenance of material and equipment were the most common (14 cases), followed by falls (13 cases), being struck (10 cases) and accidents caused by collapse of building structures (3 cases).

4. CHALLENGES CONFRONTED BY MALAYSIAN FOREIGN WORKERS

Foreign workers in Malaysia have been subjected to unequal, dangerous and unsatisfactory treatment under the hands of local employers as well as the infrastructure of the law. Jobs in the construction industry entail irregular long hours, unsafe working condition, low pay and also demands that foreign laborers work during weekends and holiday seasons. Despite all the unpleasant situations that they are would have to face, these foreign workers do not stop coming to Malaysia in order to fill the gap that local distaste have left in labor intensive jobs like those in the construction sector (Wei & Yazdanifard, 2015).

4.1. HUMAN RIGHTS

In Malaysia, foreign workers have a limited ability to enforce the rights enshrined in their contract due to the language barrier, the cost of lawyers and the period of time they are allowed to stay in Malaysia. Hence, foreign workers are subjected to psychological stress when such cases occur, as they often feel isolated and helpless when their rights go unprotected in a foreign country (Chelvarajah, 2015, as cited in Wei & Yazdanifard, 2015). Furthermore, according to a report by Amnesty International foreign workers are lured to Malaysia by promises of high salaries by the construction companies but always end up being exploited and abused (The Star, 2015). Many workers that are brought to Malaysia by agents often find themselves deceived about their pay, type of job and even their on-site accommodation. Some even find themselves locked up behind bars for flimsy and unacceptable reasons (Chelvarajah, 2015, as cited in Wei & Yazdanifard, 2015).

4.2. APPLYING WORK PERMIT

Applying for a working permit is the first difficulty most foreign worker has to overcome in order to enter in Malaysia. The application procedure is often unnecessarily complex and needlessly time-consuming (Wei & Yazdanifard, 2015). According to the official portal of the Malaysian Immigration Department, the recruitment terms and conditions for foreign workers differ from country to country. Only certain nationalities are allowed to work in some of the listed sectors whereas individuals from countries not on the list are prohibited from entering Malaysia under Section 8(3) of the Immigration Act 1959/1963 (Official Portal of Immigration Department of Malaysia, 2015).

Furthermore, there are 2 phases in the application process - pre arrival and post arrival. Hopeful workers are required to prepare a list of documents that include among them medical certificates, an approval letter, security bonds, copies of passports and their insurance policy. Besides the long waiting period of approval for the permit, a huge sum in fees have to be paid, depending on the sector and nationality of the worker, in order for the foreign workers to get an identity card that allows them to work in the sector of their choice (Official Portal of Immigration Department of Malaysia, 2015). However, foreign workers usually come from less developed countries to find a living in Malaysia, but language is often a barrier for them because they have no need to learn Malay and have limited access to English. Yet they are required to prepare a list of documents based on requirements that are written in English or Malay in order to apply for their permit.

4.3. COMMUNICATION BARRIERS

Language barrier has been a problem amongst foreign workers in the construction industry in Malaysia, especially between the supervisors and the foreign laborers in the construction site. Besides, the scenario of foreign workers influx into various sectors including the construction sectors has created a variation in language (Salleh et al., 2012). This language is often linked to communication, where according to Trajkovski and Loosemore (2006), language is the barrier for communication, whether verbal or written, when presenting information to the foreign workers.

As a result, leads to complications in the worksite as most of them cannot understand or speak the local language with their supervisors, which cause a breakdown in team cohesion due to inability to communicate. Workers also find it difficult to understand work orders, safety rules and to interpret safety warning signs. This is among the factors that contribute to accidents happening in the construction site and brings with it huge consequences to the project, such as delaying progress, injury, disability or even death of workers causing the company to be short staffed and to incur them losses from myriad compensations and from the delay (Wei & Yazdanifard, 2015).

4.4. COMPENSATION AND INSURANCE SCHEME

Most cases of injury, accidents and death are issues that can be prevented if certain precautions are taken by employers of potentially unsafe workplaces like the construction site. Most of the foreign workers do not get the benefits of compensation and insurance which they are fairly entitled to but often get cheated out of due to their lack of knowledge, which is really unfair to them (Wei and Yazdanifard, 2015). Under Section 26(2) of the Amended Workman's Compensation Act 1952, it is compulsory for every employer to insure all foreign workers employed by him under an approved insurance scheme in respect of any liability (Wei & Yazdanifard, 2015). In addition, any employer who fails to insure the foreign workers under the scheme shall be guilty of an offence and shall be liable, on conviction, to a fine not exceeding RM20, 000 or to imprisonment for a term not exceeding 2 years or both (Wei & Yazdanifard, 2015). However, there are employers who take advantage of their foreign employees by ignorance of the local laws and deny them of their rightful compensation (Wei & Yazdanifard, 2015). Therefore, while the scope of the coverage of the law guarantees benefits to the employee in the long term, it is often not enforced.

4.5. EQUAL TREATMENTS

Foreign workers always face issues in getting equal treatment with that of local workers. First and foremost, foreign workers often do not get their salary on time due to the inefficient arrangement of their employers. The punctuality of their payment does make a big difference for them and their families back home that depend on them for a living (Wei and Yazdanifard, 2015). In addition, according to Elias (2008) not all foreign workers get their salary, after conversion, on a salary scale that is proportional to that of their Malaysian counterparts, which shows the act of inequality. Besides, they also do not get equal treatment in terms of leaves, as local workers get a greater number of public holidays, sick leave and vacation leave. Their working hours are also extremely long and often longer than the government mandated eight hours a day. Foreign workers also do not get much benefit in terms of free medical treatment as well as bonuses and shift duty allowances. However, employers should not cheat their employees off of their rights but should instead provide equal and good benefits to their foreign laborers as their business is dependent on the hard work that these people put in every day (Elias, 2008).

4.6. WORKING ENVIRONMENT AND ACCOMMODATION

A good working environment at a construction site is important for all the workers so that safety and health issues can be avoided. Wei and Yazdanifard (2015) claims that most of the construction sites in Malaysia are dirty, tough and dangerous, with few of the recommended safety precautions being followed. Wei and Yazdanifard (2015) also noted that despite the unpleasant and unsafe working environment, Malaysian foreign workers are not bothered by this deficiency and are willing to take these risky jobs that locals do not wish to do just to earn a living.

Due to nature of business, there is no guarantee that construction companies will be continuously awarded projects. Hence, employers have tried their best to minimize costs by making the immigrant construction workers stay on-site in temporary accommodation known as 'kongsi' (Abdul-Aziz, 2001). The condition of 'kongsi' is generally poor and there are no proper amenities. In addition to the lack of new employment, the nature of the business is that the projects are short-term. This means that once they have completed a project, construction workers may disembark for another. This contributes to their temporary working conditions, which has repercussions on other areas of their life (Mustapa and Pasquire, 2008).

As conclusion, by having explained the several aforementioned challenges faced by foreign workers in the Malaysia construction industry, Wei and Yazdanifard (2015) further stated that this is among the factors that contributed to accidents on construction site and brings with it huge consequences to the project such as delaying progress; injury; disability or even death of workers causing the company to be short staffed and to incur them losses from myriad compensations and from the delay. Hence, employers should not cheat their employees off of their rights but should instead provide equal and good benefits to their foreign laborers as their business is dependent on the hard work that these people put in every day (Elias, 2008).

5. HEALTH AND SAFETY PRACTICES TO OVERCOME THE CHALLENGES FACED BY FOREIGN WORKERS IN THE CONSTRUCTION INDUSTRY

There are many ways in which health and safety in construction industry is controlled to reduce the number of accidents, thus reducing the number of fatalities and injuries to the workers and damage to the equipment. Governments worldwide have maintained an ongoing commitment towards establishing a working environment free of injury and disease. This commitment is reflected by establishing performance based workplace health and safety legislation which sets generalized performance objectives and provides a system of clearly stated responsibilities to encourage greater self-regulation for the construction industry. Some countries depend totally on government in controlling safety at worksite. Despite the high costs of work accidents, many construction companies adopt as their only health and safety management strategy the compliance with mandatory regulations. However, only being in compliance with these regulations might not be sufficient to guarantee excellence in health and safety performance, as they cover only minimal preventive measures (Alhajeri, 2011).

Besides, in adopting different approaches to health and safety in developed and developing countries, two main differences can be identified. The first is the existence of legislation and its effective implementation; the second is hazard awareness. In developed countries, many safety acts and legislation exist and are implemented effectively. Nominated safety officers promote hazard awareness with the help of regular safety training sessions. In developing countries, however, safety rules barely exist at all; and when they do, they are inappropriate, ineffective, out-of date and based on conditions that prevailed while the country was still being colonized. Additionally, the regulatory authority is usually very weak in implementing rules effectively, and work hazards are either not perceived at all, or perceived to be less dangerous than they actually are (Hinze *et al*., 1999).

Hence, most countries now have a law on Health and Safety at Work that protects their population from personal harm by forcing contractors; installations; equipment; tools; etc. to have a safety level that is at least at the level of the generally accepted technical level corresponding to good engineering practice. For example, safety and health in construction in the USA is regulated by governmental agencies such as the Occupational Safety and Health Administration (OSHA) which provides strict rules and regulations to enforce safety and health standards on job site. The OSHA defines safety and health regulations for construction industry. The regulations apply to all involved in construction work including contractors, subcontractors and suppliers. According to general health and safety provisions, it is the employer's responsibility to initiate and maintain programs for safe working conditions for employees. It further states that any such program shall provide for frequent and regular inspections of the job sites, materials, and equipment to be made by designated competent persons. The safety training and education regulations create a responsibility for the employer to avail himself of the health and safety training programs and instruct each employee of any unsafe conditions and regulations applicable to employee‘s work environment to prevent any hazards. Countries such as the United Kingdom, Singapore and Hong Kong have adopted a self-regulatory approach to safety, whereby proprietors (including contractors) are required to develop, implement and maintain safety management system (Ng *et al*., 2005).

In Malaysia, the Department of Occupational Safety and Health (DOSH) under the Ministry of Human Resource is responsible for enforcing the law on occupational safety and health, which was introduced in 1994. Furthermore, Malaysia was the first Asian country to have enacted a Safety and Health Act covering all occupations in 1994. OSHA 1994 was introduced to respond to the need to cover a wider employee base and newer hazards in the workplace (Salleh *et al*., 2012).Thus, every construction organization should have a clear policy for the management of health and safety so that everybody associated with the organization is aware of its health and safety aims and objectives. Besides, a good health and safety policy will also improve the performance of the organization in areas other than health and safety; help with the personal development of the workforce and reduce financial losses. It is important that each construction site throughout the organization is aware of the policy.

6. The Way Forward and Conclusions

Malaysia intends to be a developed country with the United Nations by the year 2020 and the construction industry has always been a stalwart economical key to that goal. However, the level of industrial accidents in Malaysia is still upsetting. In recent years, this industry has had to hire more to the point of being dependent on foreign workers in order to meet the ever growing demands of Malaysia's continuing thirst for new building projects. Working conditions for these foreigners are often unfavorable but this does not stop them from working in Malaysia. Besides, due to over-dependence on foreign workers has caused several problems such as low productivity, do not have enough construction experience and also may lead to the misunderstanding, which will decrease the level of project work done in Malaysian construction industry.

Therefore, the purpose of this paper was to promote a better understanding of the role of health and safety practices through identification of the challenges confronted by foreign workers in the Malaysian construction industry. The main challenges associated with foreign workers can be mainly attributed to the areas such as human-rights related problems, difficulty of applying working permit, communication barriers, compensation and insurance scheme, equal treatment, working environment and accommodation issues. In addition, it presented the main accident types and statistics in the Malaysian construction industry. Further, literature found that the types of accident such as falls, stepping on objects, and struck by falling objects are the top three most commonly accidents occurred in the Malaysian construction industry. Moreover, statistics by Department of Occupational Safety and Health (DOSH) indicated that main fatal injuries happened to the Malaysian foreign workers are fall from height, followed by stepping on, striking or being struck by objects.

The challenges encountered by the foreign workers in the Malaysian construction industry as identified in this paper raised few important questions i.e. what are the current H&S training and education programmes provided for foreign workers; what are the deficiencies in H&S training and education programmes in Malaysia; how can H&S training and education programmes be improved effectively for foreign workers working in the Malaysian construction industry to overcome their challenges and provide a safe work place. This forms the basis for the way forward of this future research with an ultimate intension of improving the H&S in the Malaysian construction industry.

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HEALTH, SAFETY AND WELFARE STANDARDS OF EMPLOYEES IN THE SRI LANKAN CONSTRUCTION INDUSTRY

K.P.L.B. Pathirana and Mahesh Abeynayake*

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Construction industry could be identified as one of the major employment opportunity providing sectors in the world wide. Due to larger operational time and use of large force of labour and machineries, risk is predominant in the construction industry. Many fatal accidents have been occurred during the project. Construction accidents are common in the Sri Lankan construction industry. Most prevailing reason in Sri Lanka when considering about the health, safety and welfare of the construction industry, could be identified as the improper safety culture. Furthermore, current Sri Lankan law do not comply with the present needs and they have become outdated.

Aim of this research is to uplift the health, safety and welfare (HS&W) standards of employees and make recommendations for effective development of construction industry. Current situation of HS&W of construction industry of Sri Lanka is identified using of expert survey research approach under quantitative research approach.

Factors contributing for the HS&W issues are examined and factors are properly ranked during the research. Then recommendations have been provided to mitigate factors. Furthermore, loopholes of current Sri Lankan Laws are identified. Overall expectation from the properly established health, safety and welfare culture is to uplift the working standards of the employer in a safe working environment. The extent of contribution from the government to achieve this expectation is well addressed through the research findings. Here amendments to be made for the out dated Sri Lankan legislation are elaborated through the findings. Contributions from the organizations to succeed the targets are also depicted.

Keywords:*Construction Industry; Employees; Health, Safety and Welfare; Sri Lanka; Viability.*

1. INTRODUCTION

Wadick (2010) demonstrated Construction industry is combined with high risk and it has recorded the fourth highest incidence of employment injuries including deaths, injuries and diseases. The higher number of work related fatalities and poor safety records show the risk in the construction sector. So it is necessary to provide attention on health, safety and welfare of employees. Wadick (2010) further demonstrated that main contractor play a central role in providing a safer work place and throughout the construction process he has the responsibility of providing matters on safety, health and welfare.

Enshassi *et al.* (2015) elaborate that construction employees mainly focus on project and they ignore their own safety and health. Usage of inappropriate equipment will increase the threat to accidents. Further inadequate safety work training is a major factor for the exposure for accidents during construction. According to Arditi *et al.,* (2006) construction operations in the night time is risky and unsafe due of the vision problems at night. Hetherington (1995) demonstrated that all the surveyors, engineers and architects involved in the construction project have a responsibility on safety towards employees and public and it cannot be ignored. Musonda (2012) depicts that health and safety tenets such as health and safety audits, health and safety meetings are not practiced by the most of the contractors. Further Yu *et al.* (2010) states that today there are many forms of intra-organizational injustice in order to obtain profits rather than thinking of the employees welfare.

*Corresponding Author: E-mail – abey92@hotmail.com

In several countries they are providing socio economic security to poor workers (John, 2004). Welfare is providing to the employees as insurance covering, family allowances, provident Funds, pensions and gratuity schemes, and widows' and survivors' allowances (Ismail *et al.,* 2012). Carby-Hall (1989) employers are bound by common law to provide reasonable care for the safety of employees. So during any circumstance employee can take actions against the employer for breach of the employer's duty of care. So he can sue against the employer for the negligence of providing safety. Further, Carby-Hall (1989) demonstrated that employer is responsible for the health and safety of every person employed or working on the premises.

When compared to the other industries the occurrence of accident is mostly higher in construction industry. The most of those accidents lead to tragedies such as injury or death to persons, damage to property and the environment and associated direct and indirect costs and effort. Therefore arrangement of guideline framework is most important to minimize the negligence about safety in Construction industry to protect values of lives as well as minimizing of economic losses as well. In currently some of legislations in Sri Lanka provide that frame work up to some extent.

The Sri Lankan construction industry focuses mainly on productivity and obtaining profits. Poor health, safety and welfare facilities prevailing in the current construction industry leading for the disappointment of employees and it inversely affect to the productivity. So this research will be an attempt to limit the gap of health, safety and welfare standards of employees in the construction industry. To achieve this, first this paper identifies and reviews the existing legislation regarding the health, safety and welfare law. It then goes on to explore the current situation of health, safety, welfare of employees in the construction industry and to review the problematic areas of providing health, safety and welfare for the employees in the construction industry. Finally, procedures are recommended to uplift the health, safety and welfare standards of employees in the construction industry.

2. LITERATURE REVIEW

A comprehensive literature review was carried out to identify the current situation of Health, Safety and Welfare of employees in the construction industry. The problematic areas and issues, extent of legislation addressing on those points are well elaborated. The construction industry could be defined as an important foundation for economic structure of a country in worldwide. It was estimated that construction industries contribute for more than 10 percent of the national gross domestic product (Havenvid *et al.,* 2016). Havenvid *et al.* (2016) further illuminated that the construction industry's economic impact on society is very huge and this may focus a significant importance when forming relevant industrial and economic policies. Sawhney *et al.,* (2014) states that today most economies are emerged through construction sector. India is a best example for that, on the other prospective it contributes for the development of the nation. Major stimulation factor for the Indian social and economic growth of the nation is the construction industry. Further Sawhney *et al.* (2014) defined Indian construction industry as one of the main key for Indian economy.

Construction companies represented 14% of total Italian enterprises and 1.9 million people were employing there. That is 10.5% of the total workforce employing in Italian construction sector Bigliardi *et al.,* (2014). Wang (2014) stated considerable amount of money is invested on infrastructure and public services by the Chinese government during the beginning of economic reform in 1980. The construction industry has been contributed to uplift the living conditions of general public in china, especially in the urban area is predominant. The average housing floor area per capita in urban China has been increased in a steady way, from 6.7 to 23 m^2 between 1978 and 2008.

The quality people must be used in the construction industry. This aspect is very important, because in recent days there is a growing shortage of qualified workers in the construction industry. They are experienced managers and skilled workforce. Specific engineering skills such as civil engineers, geotechnical engineers, structural engineers and transport engineers are considered as long term skill shortage list in New Zeeland (Chang-Richards *et al.,* 2017). Nejati and Ghasemi (2012) stated corporate social responsibility (CSR) concept has been predominant among companies and there is a significantly increased number of companies that are engage in social behaviors and activities. (Ulutas Duman *et al.*, 2016) defined Corporate social responsibility as a fast growing concept that influences organizations to account for any negative effect they have on the society and natural environment. In recent years many companies had focus on the CSR and there is a growth in companies entering in to CSR.

Professionals are bound by common ethical behaviors including obligations, duties and responsibilities that are being bound on ordinary people (Vee, 2013). Employees are usually bounded by set of principles, attitudes. (Vee, 2013) further reported the unethical behavior of Architects and they have been warned several times. Vee (2013) indicated, consideration of ethics and social responsibility is one of the major responsibility of a project manager. Vee (2013) described incalculable value of human life of building and design professionals must be considered by the management by mitigating the risk involved with them. Vee (2013) described that there were criticisms made regarding the ethical conditions such as asbestos poisoning scandal that affected many workers during 1960.

In the National Institute of Occupational Safety and Health Act, No. 38 of 2009 of Sri Lanka, it is mentioned that the Institute will advise the government on the measures required to prevent accidents and injuries relating to occupations at work places, undertake and assist in investigations and study programs, surveys and research in the field of occupational safety and health. Moreover, that there are some legislations and their amendments which lead the guideline regarding occupational health and safety such as;

- Factories Ordinance No.45 of 1942 as amended by Acts No. 54 of 1961 & No. 12 of 1976
- The Workmen's Compensation Ordinance of 1935
- The Shop and Office Employees Act No.15 Of 1954

The Factories ordinance provides guideline to ensure safety, health and welfare of workers at their work place. It’s mainly convey its rules and regulations, quality of the premises; cleanliness; overcrowding; maintain reasonable temperature; ventilation; lighting; drainage of floors and sanitary facilities. Further its asked to, the safety of the worker must be ensured by installing and maintaining the machinery, mechanisms, transmission apparatus, tools, equipment and machines in best possible safety conditions. As well as tools, equipment, machines, or products used must be organized properly guaranteeing the safety of workers. And specific conditions for the usage of internal combustions engines are verbalized such as the need to conduct the exhaust of gases from the engine into the open air; and to partition the rooms so that any harmful fumes from are not shifted to other persons. This Ordinance necessitates that no young worker (under the age of 18 years) is allowed to work on a machine unless he has been fully instructed about the dangers involved in operating the machine, has received sufficient training in that regard and is working under supervision of an experienced and knowledgeable worker.

The payment of compensation to workers who are injured in the course of their employment by an accident arising out of the and during the course of their work is illustrated in the Workmen’s Compensation Ordinance of 1935 and subsequent Amendments. occupational disease as described in Schedule III, such as Anthrax infection, poisoning by lead, nitrous fumes etc. The Ordinance also provides for compensation to be paid to the dependents of the worker, in the event of his/her demise as a result of a work related accident or occupational disease.

The Shop and Office Employees Act No.15 Of 1954 provides for the regulation of employment, hours of work and remuneration of persons in shop and offices, and for matters connected there with or incidental thereto. Therefore, it is the main document about employees working hours and their entitlement to other facilities with the work. As example, according to the act working hours on any one day shall not exceed 8 hours, and in any one week shall not exceed 45 hours. This rule is not applicable to any person who holds an executive or managerial position in a public institution.

2.1. HOW CONSTRUCTION COMPANIES ENSURE HEALTH, SAFETY & WELFARE STANDARDS?

More than 30 people on average are admitted daily to the Colombo National Hospital due to the rising number of workplace accidents. Last year, more than 12,000 out of a total of 121,032 people admitted to the hospital had been injured in accidents at work, the National Coordinator (Training) of the Accident and Orthopedic Service. Therefore, it is more important to strengthen the current laws and regulation to protect our valuable human resources as well as minimize the economics losses. At the moment before said regulation are giving high power to minimize negligence of management and workers, related to occupational health and safety in Sri Lankan construction industry. Therefore, it was help to maintain occurrence of accident in this booming construction industry. Moreover, that most of construction companies of Sri Lanka now maintaining international occupational health, safety and welfare regulation to maintain and promoted their goodwill within the industry such as;

- ISO 9001 is the international standard that specifies requirements for a quality management system (QMS)
- ISO 14001:2004 specifies requirements for an environmental management system
- OHSAS 18001, Occupational Health and Safety Assessment Series

2.1.1. HEALTH AND SAFETY ISSUES OF EMPLOYEES

According to De Silva and Wimalaratne (2012), magnitudes of construction industry based accidents remain at a higher level in Sri Lanka when compared with other countries such as USA, UK, Hong Kong and Singapore although the construction output is less in Sri Lanka when compared with developed countries. The authors revealed a recent tragic accident caused by a falling beam from a temporally constructed roof on to the head of a medical student when she was passing near the construction site. She was disabled. Further, the author identify that working environment of the construction industry could be as more hazardous when comparing with the other industries. Labour intensive work prevailing in the Sri Lankan construction industry and comprised of skilled and unskilled workforce. They are with different educational backgrounds and this would be a cause for higher potential of personnel injuries (De Silva and Wimalaratne 2012). Degree of health hazards and risk exposure varies from worker to worker according to the job they are engaged in. De Silva and Wimalaratne (2012) reported masons, carpenters, roofers, plumbers, electricians, workers engaged with finishing and painting, welders, tillers, and unskilled labours could be identified as most vulnerable employees for the site hazards. Recent findings have been revealed several causes for most of the site accidents. Unsafe electrical connections and poorly maintained electrical equipment, falling of improperly secured boards, planks and decking are some of the causes.

De Silva and Wimalaratne (2012) stated 60 percent from fatalities are due to head injuries caused by fall. Falling objects, exposure to harmful gases are some of the causes for injuries and fatalities in the local industry. De Silva and Wimalaratne (2012) identified reasons for week OSH performance in the construction industry such as improper safety management systems, regulations, resources, policies and commitment. They identified reasons for week OSH performance in the construction industry such as improper safety management systems, regulations, resources, policies and commitment. Further main causes for the unfortunate situations in the site works are lack of usage of safety gears. According to the survey (De Silva & Wimalaratne, 2012) found that heavy sweating under tropical conditions, hair losses, and falling of the helmet during working, are the main rejection factors of the workers on personal protective equipment. De Silva and Wimalaratne (2012) exhibited that Dengue could be identified as a reasonable threat for the construction workers.

Accordingly De Silva and Wimalaratne (2012) to calculate the injury and health hazard rates, there is no any internationally accepted methodology. Furthermore there is no approved system to define the injury type or pre-defined weightages for the different percentages of risks. Commonly accepted criteria are the ILO classification for injuries and health hazards. Hare et al. (2006) viewed the idea of effective planning would have been reduce the accidents and ill health of site personnel and prevent most of them. (Hare et al., 2006) stated that main contractor has a responsibility of managing the health and safety risk of the workers and supervising the site activities.

2.1.2. WELFARE ISSUES RELATED TO THE CONSTRUCTION EMPLOYEES

Loosemore and Lim (2016) formative theory of justice illustrated that the concept of justice is embedded with the two principles of liberty and equality. The liberty principle depicts that every person has a range basic rights and freedom to enjoy and the equality principle viewed that employment should be open to any person disregard of background, ethnicity or gender. There is a high rate of fed-up employees among construction workers, who are with the belief that they must work long hard hours in the course of their daily work. Loosemore and Lim (2016) stated that many intra-organizational injustices prevail in the current construction industry. Workforce causality rate becoming high, under representation of women and other minority groups, racial discrimination, corruption and poor safety are some of them. Today most of the enterprises are being survived only for the profits rather than their individual and collective welfare.

Loosemore and Lim (2016) thoroughly stated According to the report and various other studies, construction industry and relevant projects are the main hub for corrupted business practices namely bribery, intimidation, threats, collusion and frauds. Discrimination and racism would also continue to prevail on workplaces at higher levels more than in the general population and construction workers' safety and well-being have also proven to be predominant problems, despite many years of initiatives and reforms in various parts of the world.

Loosemore and Lim (2016) various reports revealed that construction industry migrant workers have suffered much with the injustice, they have to face a lower plight when working with Australia, UK, Middle East, China, Brunei and Singapore and many other countries. The illegal construction in Australia have deprived the basic human rights including fair pay, safe working conditions, pensions, insurance and other forms of protection such as sick leave, annual leave and redundancy payments. The illegal construction in Australia have deprived the basic human rights including fair pay, safe working conditions, pensions, insurance and other forms of protection such as sick leave, annual leave and redundancy payments.

2.1.3. CURRENT STEPS TAKEN TO MAINTAIN STANDARDIZE WELFARE FOR CONSTRUCTION EMPLOYEES

Managers are advised to make use of a system that identifies and reward Workers who serve in a perfect way. This will encourage the worker participation. Here workers are provided with financial bonuses for identifying ways to improve the quality of their company's operations. The money is a powerful motivator and productivity of labours could be increased through a well-design reward system. Also employee efforts must be extra paid. The construction employees must be provided with proper recognition. It is believed that apart from financial incentives, recognition is also considered as a proper means to inspire enthusiasm among employees.

Schuler and MacMilan (1984) forwarded the idea of employee participation in the management of pension schemes. Here pension schemes become a remuneration package for the workers. Schuler and MacMilan (1984) highlighted the development of private medical schemes is a recently taken initiative. Furthermore they stated that internal promotions will polarize the labours and workforce. Employees are transferred in to a relatively senior ranking, benefit from a capital sum in the form of a golden handshake, hence this will enrich the employee welfare.

3. RESEARCH METHODOLOGY

This research provides number issues related to health, safety and welfare of employees in the construction industry of Sri Lanka. Massive number of information available relation with the research topic. But for the convenience, sample includes skilled employees, unskilled employees in the western province of Sri Lanka. The third limitation is the significantly small sample size. A larger sample could produce different results by addressing different class sections and multiple cases. Future studies should focus on a specific category (small, medium-sized construction organizations) to achieve more detailed information. The generalization of the research findings can also be considered as a limitation of this research. After capturing the research problem, a comprehensive literature review was conducted to explore the Health, Safety and welfare standards of employees in the construction industry and its influence on the construction sector. Journal articles, electronic sources, books and unpublished dissertations became the supportive sources when conducting the literature review.

Quantitative research approach based survey approach was used to collect data for this research (Mix method approach). It consists of semi structured interviews from industry experts followed by detailed questionnaire survey from construction professionals. Viability of data gathered from the expert interviews are checked and ranked during the analysis of questionnaires of construction professionals. The questionnaire survey findings were analyzed using Relative Importance Index. Three degree, four degree and five degree relative important index (RII) formulae have been used to analyze collected data.

4. DATA ANALYSIS AND RESEARCH FINDINGS

All the respondents revealed that currently good safety culture is not established in the construction industry of Sri Lanka. All the respondents have revealed that there is not even supervision safety culture in Sri Lanka. One of the respondent reveled that after the supervision also labours are trying to adjust to the previous situation. They are using safety helmets and other PPE when safety officers are there in the site and when the officers are not there, they behave without PPE. Also current safety procedures in Sri Lankan construction industry is very much poor.

4.1. HEALTH AND SAFETY ENHANCEMENT PROCEDURES FOLLOWED BY ORGANIZATIONS

Here company x owns OSHA'S 18001, ISO 14001, ISO 9001 for the HSW. It can be called as one of the best safety established company in Sri Lanka. The company x is going far beyond Sri Lankan law and regulations, hence they follow foreign standards to provide best health, safety and welfare provisions for the employees in Sri Lanka. All the other local companies are always below the standards provided by the company x, as they follow only laws and regulations.

- Use of personnel protective equipment (PPE)
- Induction programmes - If a new employer / staff member come in to the company, he must undergo with an induction programme.
- Conducting Pep talk - Work related employees are participated for the event. It is conducted when starting a new work by the site in charge officer. He investigates the unsafe acts and unsafe conditions embedded in a work and provide reasonable solutions to those issues. Here worker have to tick for the relevant work that he is carried out. Next he has to identify the hazard relevant to that work, from the list of hazards. In the right side there are relevant precautions and can be easily identified by the workers.

Work		Hazard			Relavent Precausions
w1	√	H1	√	→	P1
		H2			P2
		H3	√	→	P3
W2	√	H1			P1
		H2	√	→	P4
W3					
W4					

Figure 1: Format of a Safe work Start Chart

- Conducting Tool box talk
- Conducting special training programmes and special safety meetings
- Risk Assessment

4.2. WELFARE ENHANCEMENT PROCEDURES FOLLOWED BY PRESENT ORGANIZATIONS

Respondent A commented that they are providing Rs. 5,000.00 package for one worker who is newly entering in to the site. This package is provided in the form of safety shoes, safety helmets, Safety belts, nets, beds and mattresses. In addition to that all the organizations are providing accommodations, medical facilities, water and sanitary facilities at different levels.

4.3. FACTORS CONTRIBUTING TO HS&W ISSUES

- Low management commitment and poor budget allocation

According to the common ideas of respondents, top level management do not understand the hidden benefit of enhancing HSW in the construction site. Management runs only on profit. They pay lees time, money, and attention on HSW of the site. According to the expert responses during the interview, they expressed that management is negative minded and they are thinking that HSW is an extra cost and extra burden for the company. Hence they issue limited money and poor budget allocations on HSW.

- Poor knowledge of workers on health, safety and welfare

Workers have poor knowledge regarding HSW and especially they do not wear the chin guard of the safety helmet. So they are quiet close to the hazards. Furthermore, workers bear a negative attitude; safety is an extra burden for them. Especially workers do not know what their rights are, what are the facilities they can get from the management and people are unaware about the ways of getting those benefits.

- Senior officers are not concerning on health, safety and welfare

Executive officers must be an example to their subordinates and they must wear full body kit when entering in to the site. So workers have a trend to follow safety procedures by following the executive officers. But in the practical life executive staff is reluctant to be an example for the workers and run on construction targets.

- Low labour attendance for the Safety programmes

Labour attendance is very low for the Tool box talk and morning awareness programmes. The reason behind may be, these meetings are conducting early in the morning and people feel lazy after working a whole day.

- Lack of qualified officers on HS&W

There is a shortage of qualified officers in the field of health, safety and welfare. Actually other professionals have a little knowledge on HSW.

4.4. *LOOPHOLES OF CURRENT SRI LANKAN LAWS AND REGULATIONS*

In Sri Lanka most of the construction accidents has been occurred due to work at height. However factories Ordinance (1942) does not address the relevant precautions for the accidents caused by work at height. In Sri Lanka Ordinances came before the independence (1948) and Acts came after the independence. Respondent D reveal that Factories Ordinance and all the legislation are outdated now. They did not discuss on current issues such as construction hazards. According to the Respondent E, in Sri Lanka maximum compensation for a fatal accident is Rs. 515,000.00. This is not reasonable and this amount should be increased.

At present construction companies must handle a health and safety team according to the CIDA grading. Also these team members must be working before six months in the relevant organization and cannot recruit professionals when the project proceedings began. Now NIOSH is conducting NIOSH diploma programme. This is to produce well qualified and trained professionals for the health, safety and welfare sector.

4.5. *HEALTH AND SAFETY ENHANCEMENT PROCEDURES FOLLOWED BY PRESENT ORGANIZATIONS*

All the sites (100%) are providing PPE for the workers. Also, all the organizations (100%) using HSW notices to communicate information to the work force and other employees. All the other safety procedures are practiced at a satisfactory level in the contracting organizations but least number of organizations (16.67%) is rewarding their workers for the safe behavior. Also limited number of organizations (43.33%) is asking the ideas of employees on health, safety and welfare problems. This is quiet bad situation as employee ideas are more valuable in uplifting the HSW of the site.

4.6. *FACTORS CONTRIBUTING TO HS&W ISSUES*

Respondents have been identified inadequate facilities for health, safety and welfare officers and supervisors as a major contributing factor for HSW issues. They have marked 82.00 RII percentages and ranked as 1. Poor budget allocations on health, safety and welfare are directly contributing for the poor adherence to the HSW laws and regulations. They have marked 74.67 RII percentage value and ranked as second contributing factor.

Respondents have been identified workers reluctance to follow health, safety and welfare rules as the last contributing factor for the poor adherence to the HSW laws and regulations. They have marked 60.00 RII percentage value. The main hidden reason behind the negative responses is workers can be forced to follow health, safety and welfare rules through proper supervision.

Also respondents have been identified attitude and habit of the workers and employees is a minimum contributing factor. They have marked 61.33 RII percentages because Workers attitudes and habits can be easily changed though proper training.

4.7. *WELFARE FACILITIES PROVIDED AT THE CONSTRUCTION SITES*

Respondents have identified toilets and sanitary facilities is satisfactorily providing by least no of companies. They have marked 48.89 RII percentage and ranked as 11, low level providing facility. Furthermore respondents have identified extra allowance for workers at risk are not satisfactorily providing by the construction organizations. They have marked 51.11 RII percentage, ranking it as 10.

Other welfare facilities such as proper lighting and good working climate, proper drinking facility, security, medical facility and canteen and cocking facility are satisfactorily providing by most of the construction organizations.

Table 1: Types of Accidents Occurred at Site

Categorization	Type of accident	F %	S %	M %	N %
a	Falling from an elevation	13.33	20.00	6.67	60.00
b	Electrocution	6.67	16.67	20.00	56.67
c	Struck by equipment / vehicle	10.00	13.33	36.67	40.00
d	Struck by falling material	0.00	23.33	40.00	36.67
e	Burn or explosion	6.67	10.00	16.67	66.67
f	Chemicals and toxic materials	3.33	6.67	10.00	80.00
g	Plant and equipment related accidents	3.33	20.00	43.33	33.33
h	Any other	3.33	13.33	30.00	53.33

From the above Table 1 it can be concluding that large extent of fatal accidents (13.33%) is caused due to work at height. From electrocution considerable amount of minor accident (medical leave up to 3 days) percentage is reported (20%). Second highest percentage of fatal accidents (10%) has reported due to struck by equipment / vehicle. There is no any fatal accident reported from struck by falling material, but huge percent of minor accidents have created (40%).

4.8. KNOWLEDGE OF PROFESSIONALS ON LAWS AND REGULATIONS

Respondents have been identified National Institute of Occupational Safety and Health Act 2009 as a well know act by majority of professionals in the construction industry of Sri Lanka. They have marked 78.33 RII percentage and top ranked. Respondents have been identified National Minimum Wage of Workers Act 2016 as the second well known act in the construction industry of Sri Lanka. Workmen's Compensation Act has been identified as the third well known act in the construction industry. They have marked 70.83 RII percentage. All those acts are Sri Lankan acts and definitely that should be well known by each and every construction professionals.

Respondents have been identified Factories Ordinance 1942 as the fifth known act, related to health, safety and welfare in the construction industry of Sri Lanka. They have marked 60.00 RII percentages. Actually Factories Ordinance (1942) is a major act discussing HSW in Sri Lanka. The awareness of construction professionals on Factories Ordinance (1942) is very poor and not satisfactory.

5. CONCLUSIONS

Today most of the contracting organizations have no well-established safety culture and organizations mainly run on target achievements according to the construction schedule. Organizations collectively thinking that expenditure for safety are useless and it will gain nothing on allocations to health, safety and welfare. Further organizations are with the view of, HSW should be maintained in order to satisfy the government and mainly it is limited to the documentation only. During the research main focus has been provided on identifying factors contributing to Health, Safety and Welfare issues. These factors are identified from expert interviews and the most contributing factors are selected from the analysis of questionnaires. Furthermore it is transparent that prevailing laws and regulations must be subjected to amendments to cater the present needs.

6. RECOMMENDATIONS

It is highly recommending that employees must be given a prominent place to express their ideas. It will be more beneficial when conducting Safety training programmes and induction programmes. Also proper monetary allocations should be provided on HSW of the construction site. Especially through the contract documents, proper monetary allocations must be kept on HSW enhancement. When considering about the Laws and Regulations of Sri Lanka related to HS&W, many amendments must be implicated. Compensation during a fatal accident must be increased by law up to a reasonable amount with the mediation of Labour Department. Also government Safety department must appoint a separate inspecting officer (Consultant Officer) for each and every construction site during the period of project proceedings to monitor the health, safety and welfare. Also these government officers should be away from bribes.

Safety issues are considered only after an accident occurs at a construction site with follow up measures to improve working conditions. Construction safety on project sites is of utmost importance due to the nature of the construction industry. It is usually concern in a market-driven society where the main concern is completing projects at the required quality with minimum time and cost. Further economically it is important as it also lead to delays in the construction process. The delays and total expenses following an accident are usually much higher than the original cost of establishing and maintaining safety standards. Therefore it is understood that the safety evaluation and control save money and resources. In Sri Lankan contest, there are some laws and regulation to guide health, safety and welfare rules in construction industry. It's not cause to cover all preventions of accidents in construction industry. Accordingly Occupational health, safety and welfare matters of Sri Lankan construction industry are developing with labour laws and regulations as well as international policies.

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IMPACT OF INEFFECTIVE TENDERING PROCESSES ON CONSTRUCTION PROJECTS

N.A.J.N. Srimal, Vijitha Disaratna and P. Ganeshu*

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Tendering process is the method adopting in procurement for the selection of the contractor, who is responsible for carrying out the construction works. The tendering process is built up with several functions, performed by main tendering stakeholders. Certain substandard practices of the stakeholders during the tendering process create an ineffective tendering process. It directly results in adverse outcomes during the post contract stage of a construction project. Due to the high involvement of these ineffective tendering outcomes, the construction project is impacted adversely and may fail in fulfilling the project objectives effectively. The research investigated the impact of the ineffective tendering process to the construction project and it was equipped by questionnaire survey while the analyses are carried out in a specific analysis method developed for this research.

Initially the research found the contribution of the substandard practices to cause the ineffective tendering process. Then the probabilistic impacts to the construction project were investigated through the probabilistic outcomes from the ineffective tendering process. Additionally, the research has brought some effective solutions to mitigate ineffective tendering process.

The findings of the research indicated that the effect from the ineffective tendering process to the construction project can be mitigated by properly following the governing tender rules, adhering to good codes of conduct and ethics, managing the future risks during the estimating process by the bidders and maintaining better communication during tendering.

Keywords: *Ineffective Tendering Outcomes; Ineffective Tendering Process; Tendering Process; Tendering Stakeholders.*

1. INTRODUCTION

Tendering is a process starts with inviting the bids from interested contractors to carry out specific packages of construction work (Contracts & Law, 2011). Further, it is worth remembering that every activity in the tendering process has a time and cost implication. An appropriate tendering procedure should ensure that the client obtains a competent service at a realistic price (Brook, 2004). Tendering processes in the construction industry are fragmented and different with compared to other domains tendering practices. Managing tender procedure in construction procurement is often very complex (Mohemad *et al*, 2010). It is generally believed that wrong tendering practice is a major contributor to the construction industry's inefficiency (Ayeni, 1997). Mistakes, errors and other weaknesses occurred during the tendering process will be reason to turn the whole tendering process ineffective (Milne, 1980).

Any failures during the tender phase can cause problems during the operating or delivery phase (Business Teacher, 2008). Central Vigilance Commission-Government of India (2002) point out that the ineffective tendering process cause by some factors which contains conflicting, vague and ambiguous provisions especially in the tender documents. It results undesired outcomes such disputes, delays and financial losses in the post tender stage. Those outcomes create impact on construction projects such as cost overrun, time over

*Corresponding Author: E-mail – sunganesh21@gmail.com

run and quality issues (Sunday, 2010). The tendering process is subject to some legal actions and policy requirements as solution to avoid delays, complaints, criticism and even litigation (Ashworth, 2006; Business Teacher, 2008). Accordingly, it is clear that, various shortcomings can be occurred in the tendering process. Even though this is an undeserved for the construction project, tendering in an ineffective way is already visualized practically in Sri Lankan context. When taking in to the consideration of past researches on the topic of tendering, most of the researchers studied about estimation and not related to whole tendering process. It is hardly found a research concentrate on this impact on ineffective tendering process. Therefore, it clears a path to carry out this research on investigate the impact of ineffective tendering process to the construction project in order to propose solutions to mitigate the impact through identifying causes and outcomes of ineffective tendering.

2. LITERATURE REVIEW

2.1. FACTORS LEADING INEFFECTIVE TENDERING

Involvement of parties in construction industry creates the factors which leads ineffective tendering in construction industry. Accordingly, Ineffective selection of tendering method, it means incorrect choice of the method to selecting a suitable contractor resulting unsuccessful project. Selection method need to be considered carefully to select best among the available contractors (Smith, 2000), Poor participation of the bidders also leads improper contractor selection as potential contractors may not participate (Brook, 2004; Nkado *et al*., 2009). Therefore, proper contractor selection is essential to the project success. Further, authors said that Changes in project requirement during the tender process after the bid submission also can lead the unwanted outcomes in projects as variation and delay. Issues with information (Brook, 2004), Ineffective tender evaluation (Business Teacher, 2008), Communication gaps between consultant and bidders, consultants need to pass all information regarding bid to bidders to get quality bids which helps to avoid outcomes such as cost overrun and time overrun (Ramus *et al*., 2006; Business Teacher, 2008). Above factors are identified as consultants' drawback. Further, in tendering process, estimating errors (Smith, 2000; Potts, 2008), poor responsiveness of the bid (Business Teacher, 2008), are identified as bidders' drawbacks. Ethical problems (Ray *et al*., 1999; Palaneeswaran & Kumaraswamy, 2000; Sidwell *et al*., 2001), Documentation errors in the tender document and arithmetic and documentation errors of bidders can be lead ineffective tendering (Ramus *et al*., 2006, Samantha, 2007; Business Teacher, 2008) are identified as both consultant and bidders drawbacks. Those drawbacks considered as the factor affects tendering process gives undesired outcome in the construction projects.

2.2. OUTCOMES OF THE INEFFECTIVE TENDERING PROCESS

Dalrymple *et al*. (2006) indicated the implied message that the cost of tendering is significant among the project cost. Cost of preparation of tender documents by consultant, cost of preparation of response to tender by potential contractors and cost of assessment of submitted tenders are the costs occur during tendering process. Ineffective tendering is affect severely to the cost of tendering. More to the point, if these costs are not managed effectively then they can be quite significant and not provide proportionate returns from the tendering process (Dalrymple *et al*., 2006). Retendering is more expensive process and much more expensive than the original transaction. The additional costs of re-tendering will affect not only the principal but also the new tenderers (Ray *et al* 1999). Improper tender process may cause inefficient tender submissions and leads retendering (Hutchinson, 2008; Northwest Territories, 2009).

Mohammad *et al* (2010) found some cases which the variations are required because of the consultant's failures during the tendering period. Those are changes in project requirements, errors and omissions in design, conflicts between contract documents, inadequate scope of work, and inadequate information given in tendering. Tendering issues are identified as main reason leads to delay and disputes on during the contract period due to tender document with any ambiguity, lack of facts or confusion , inviting tenders on incomplete drawings and inadequate information (Smith, 2000; Potts 2008; Sunday, 2010) . The most tender-related claims against consultants involved alleged errors in the underlying design for the project (Berezowskyj, 2009).

2.3. *IMPACT OF THE INEFFECTIVE TENDERING OUTCOMES*

Time delay in completion schedule and variations in construction projects are the major reasons for time overrun and cost overrun (Central Vigilance Commission-Government of India ,2002; Sunday ,2010; Baloyi & Bekker 2011). Unethical behavior causes a consequential decline in the quality of project (Adnan *et al*., 2012). On the other hand, variations in the project also may cause quality degradation of the project (Fisk as cited in Sunday, 2010). Consultant has to pay more attention on it whenever variation, claims and disputes arise in the project. (Arain & Pheng, 2006) argued that increasing variations, claims and disputes in the project is a ground to overburden the consultant's contract administration process (Potts, 2008). Kashiwagi and Murphy (2004) emphasized that disputes arisen in the construction project is a great potential for financial loss. Further, Potential bidding errors, reducing markup for winning tender will result in lower job profitability of the contractor (Davidson & Maguire, 2012). It is obvious to say that the disputes may result in minimizing the contractor's profit unless otherwise it results in financial loss (Semyalo *et al*., 2012).

2.4. *SOLUTIONS TO MITIGATE THE IMPACT*

Avoiding ineffectiveness of the tendering process will reason for minimize the terrible outcomes and impacts in the project. For that, consultant has a legal duty to ensure that the tender rules are followed and that all bidders are treated fairly (Berezowskyj, 2009). Further author said that adhere good code of conducts and ethics helps to prevent from unethical issues with all parties in tendering process. When tendering, Contractors should manage the risk of being required to perform unexpected indispensable works (Business Teacher, 2008; Yeoh, 2010). A special care should be taken in the tendering process regarding the receipt, recording, assessment and confidentiality. Simultaneously, audits may be undertaken at any stage of the tender process for safeguard the employer (Capital Development Guidelines, 2011).

Since, the contractor will be reliant upon the information provided by the Principal. It is important to and communicates properly to manage the risk of being required to perform unexpected indispensable (Yeoh, 2010). Further, it has been mentioned that it is mandatory to the contractor to request further information or clarification from the Principal where the information is ambiguous, or appears to be incomplete and not rely fully upon the accuracy of any information provided by the Principal.

When estimating, using a good estimating package and reviewing bid is must. Once the contract is awarded, the actual costs must be routinely compared to the original bid in order avoid profit minimization (Davidson & Maguire, 2012). Sub-contractors need to be reviewed for completeness as well as vendors should be requested to submit a written confirmation of their bids to avoid problems in post contract stage (Levy, 2002).

3. RESEARCH METHODOLOGY

This research is based on survey approach to achieve its aim and objectives. Convenience sampling is a common nonprobability method adopted for this research. Chief quantity surveyors, project managers, director/ general managers who are involved in tendering process and experienced participants on pre contract and post contract practices were involved in this survey from both contractors and consultancy organization. 40 questionnaires were issued and 32 of them were responded.

Required information was identified through literature review. Then all of those were listed out in questionnaire to identify the impotency of the findings identified from the literature in Sri Lankan context. Questionnaire was designed in a manner to get the maximum effective answers from the respondents. Descriptive statistics were utilized for analyzing. Descriptive statistics includes the methods of organizing, summarizing and presenting data in an informative way (Jayasinghe, 2010). Mode, mean, weighted mean and probability of occurrence were used as data analysis tools.

Weighted Mean was used to analysis the level of outcome from ineffective tendering and identify the level of impact of each outcome and rank the mitigate solution. Weighted mean calculation illustrated below.

$$\text{Weighted mean} = \frac{\sum(Wi \times Fi)}{\sum Wi} \qquad \text{Eq. (01)}$$

Where, Wi = weighting factor and Fi = Frequency of response

In addition to that probability of happening these identified outcome and possibility of impacts were analyzed by probability theory as given below.

$$\text{Probability (P)} = \frac{n(A)}{n(S)} \qquad \text{Eq. (02)}$$

Where, $n(A)$ = number of responses and $n(S)$= Sample space

4. DATA ANALYSIS AND RESEARCH FINDINGS

4.1. CAUSES OF INEFFECTIVE TENDERING

The respondents have been asked to rate the given factors considering their relative influence to cause adverse effect to the tendering process based on a five point Likert scale where 1 to 5 rates indicated 'poor influence' to 'significant influence' respectively. Thus, the mean value of these ratings were analysed and the following results have been taken.

Table 1 : Rankings of the Causes of Ineffective Tendering

No.	Factor	Mean Rating	Rank
1	Ineffective evaluation of received bids	4.25	1
2	Wrong selection of the tendering method	4.13	2
3	Issues in provided tendering information	3.94	3
4	Errors in the tender documents	3.88	4
5	Changes in the project requirements by the employer	3.84	5
6	Poor communication	3.81	6
7	Bad ethics of the consultants	3.78	7
8	Design changes by the consultants	3.69	8
9	Poor responsiveness	3.63	9
10	Bad ethics of the bidders	3.59	10
11	Poor participation of the bidders	3.50	11
12	Estimating (pricing) errors	3.03	12
13	Arithmetic and documentation errors of the bidders	2.63	13

Errors in the tender documents and arithmetic and documentation errors of the bidders have been suggested by most of the authors in the literature review. Nevertheless, out of all the causes of ineffective tendering process, 'Ineffective Tender Evaluation' has become a crucial reason to create an ineffective tendering process followed by 'wrong tendering method selection' and 'issues in providing tendering information respectively. Consequently, the factor 'arithmetic and documentation errors in the bidders' have least possibility to create ineffective tendering process.

4.2. INEFFECTIVE TENDERING OUTCOMES

Outcomes of the ineffective tendering which had been identified in the literature review were verified from the questionnaire survey in order to find out "to what extent ineffective tendering leads such outcomes?" The summary results are given in Table 2. Here weighted mean was calculated by considering the mean value of each factors identified in prior objective as a weighted value and frequent considered as how many responses were given by respondents under each outcome (respondents were allowed to mark more than one out come due to each factor causing ineffective tendering). Probability of outcome was calculated to indicate the degree of possibility of forming such outcomes by the ineffective tendering process. It was arrived through dividing number of respondents responded for an outcome by total number of respondents.

Table 2: Summary of the Analysis on Ineffective Tendering Outcomes

Outcomes	Weighted Mean	Probability of Outcomes	
High tendering cost	5.19	1/6	16.23%
Re-tendering	8.30	1/4	25.95%
Variations and extra-works	11.52	1/3	36.00%
Disputes	14.49	4/9	45.28%
Delay	12.13	3/8	37.92%

Specially, Claims and disputes could be able to identify as the most probable outcome from these outcomes of the ineffective tendering process. On the other hand, high tendering cost is relatively lower probable outcome due to ineffective tendering process. Identically in the literature findings, most of the authors suggested claims and disputes and less number of authors suggested high tendering cost. Hence the percentage of the outcomes was calculated considering probabilities of all five outcomes together.

4.3. IMPACT ANALYSIS OF INEFFECTIVE TENDERING

Each respondent had to compare between identified outcomes and the impacts in order to decide the possibility of causing each impact by each outcome separately in a value from 0 to 10. To identify impact value, all given value for particular impact due to each outcome was added and multiplied with probability of Outcome. Impact value identified by using following formula,

Impact Value = Total of Possibility values x Probability of Outcome

For example, given total possibility value of cost overrun due to high tendering cost = 96 , Probability of high tendering cost outcome = 1/6 =0.17 , therefore, impact value = 96 x 0.17 = 16.32 as given below.

To identify the probability of impact, total impact value of each impact from all outcomes were calculated and divided by total possible impact value. (Total maximum possible impact value is arrived by considering Maximum value 10 for 5 out come from 32 respondents = 10x5x32=1600).

For example, Total impact value of cost overrun due to all five outcome = 306.78, Total maximum possible impact value = 1600. Thus, probability of impact = 306.78/1600 x100 = 19%

Impacts of ineffective tendering due to each outcomes and calculation of impact value of each impact and probability of impacts are shown in Table 3.

Table 3: Impact Values and Probability of Impacts

Impacts / **Outcomes**	Cost overrun	Time overrun	Lower project quality	Overburdened contract administration	Financial loss	Less profitability
High tendering cost	16.32	3.57	8.5	9.01	4.76	4.93
Re-tendering	29	55.75	11.25	16.25	9.25	6.75
Variations and Extra works	93.06	82.83	22.44	54.78	16.17	18.81
Claims and disputes	109.12	98.12	51.48	85.8	62.48	53.24
Delay	59.28	116.28	48.26	53.96	50.16	52.06
Total impact value	306.78	356.55	141.93	219.8	142.82	135.79
Total possible impact value (Maximum)	1600	1600	1600	1600	1600	1600
Probability of Impact	**19%**	**22%**	**9%**	**14%**	**9%**	**8%**

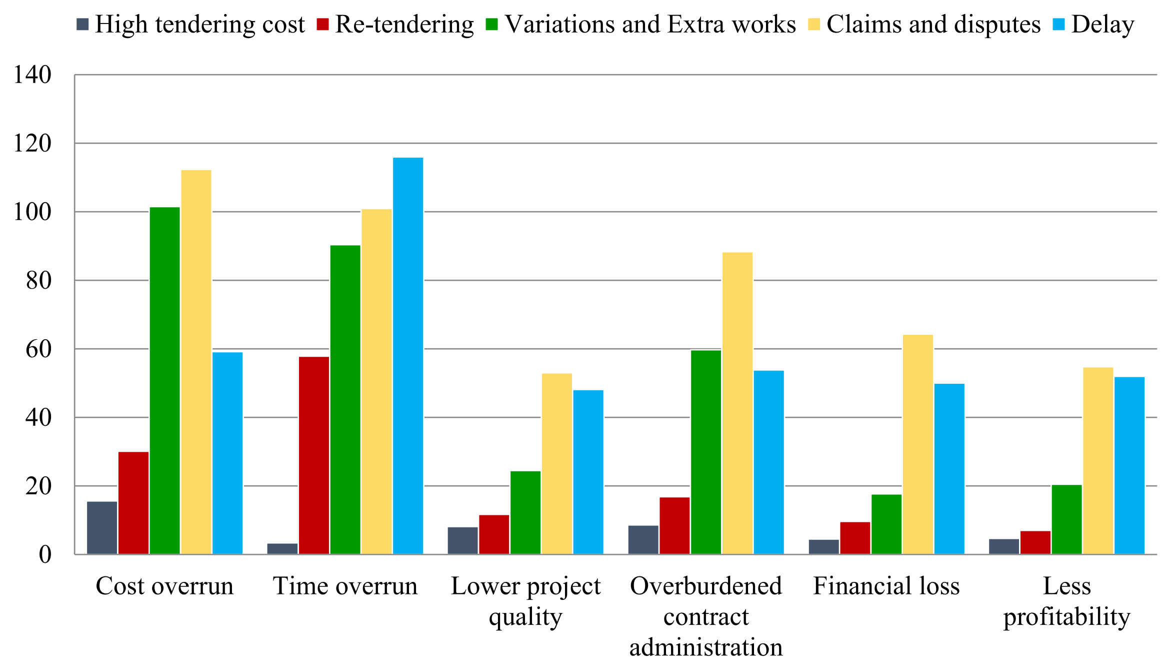

Figure 1: Comparison between Outcomes and Impacts

The comparison between all five outcomes in each impact as well as each outcome in all six impacts simultaneously. Above chart has drawn based on the impact values given in Table 3. Therefore, the height of a column represents the possibility of occur an impact due to an outcome.

According to Table 3 and Figure 1, it can be said that time overrun and the cost overrun are relatively most possible impacts among the others. As per findings from the literature, each outcome creates the impact in construction industry. Variations and extra works and claim and disputes are identified as most undesired outcome as it's create high level impact in construction projects. High tendering cost and Retendering provides comparatively low impact.

As per the literature review, financial loss and less probability were suggested by most of the authors. On the other hand, time overrun, cost overrun and overburdened contract administration were suggested by respondents. Respectively, lower project quality, financial loss and less probability took place.

4.4. *EFFECTIVE SOLUTIONS FOR MITIGATING THE IMPACT OF INEFFECTIVE TENDERING*

According to Table 4, the solution 'Following the governing tender rules in proper way' has become the best solution to mitigate the impact of the ineffective tendering process being most significantly effective solution out of all the solutions. In that order, adhere proper code of conduct, managing future risk during the estimation process, drawn a special care on receipt, recording and assessment in the tendering process, and maintain a better communication during the tendering took place. The analysis stresses that none of the identified solutions are poorly and lowly effective with having the mode of 1 or 2. Similarly, based on the literature findings also, following the governing tender rules in proper way and adhere code of conduct & ethics were suggested by comparatively large number of authors than other solutions. Thus, following those solutions help to mitigate the drawbacks causing ineffective tendering.

Table 4: Analysis on Solution for Ineffective Tendering

No.	Solution	Mode
1	Following the governing tender rules in proper way	**5**
2	Adhere code of conduct & ethics	**4**
3	Managing the future risks during the estimating process by the bidders	**4**
4	Drawn a special care on receipt, recording and assessment in the tendering process	**4**
5	Maintain a better communication during the tendering	**4**
6	Requesting further information & clarification where the information is ambiguous	**4**
7	Using a good estimating package	**4**
8	Holding frequent audits in tendering process	**4**
9	Cost monitoring & controlling during construction with the cost plan of the tender	**4**
10	Not fully rely upon the information provided by the consultants	**3**

5. CONCLUSIONS AND RECOMMENDATIONS

Even though the tendering process is more important, less care and attention is drawn towards the tendering process by the practitioners that results several issues. This research has identified those issues as factors causing ineffective tendering process. Due to these factors, the effectiveness of the tendering process is decreased. Outcomes, impacts due to these factors and solutions to mitigate those factors are researched through this study.

According to the overall view of the professionals, time overrun, cost overrun and overburdened contract administration were identified as most critical impact on construction projects due to ineffective tendering. Claims and disputes, variations and Extra works and Delay are the undesirable outcome which causes those impacts.

Ineffective evaluation of received bids, Wrong selection of the tendering method, Issues in provided tendering information, Errors in the tender documents, Changes in the project requirements by the employer were identified as most critical factors which cause adverse outcome and impact on construction project.

Those factors or drawbacks need to be avoiding in tendering process to achieve proper tendering process and mitigate the impacts. This research recommends some solutions to overcome from these drawbacks such as following the governing tender rules in proper way, Adhere good code of conduct & ethics, managing the future risks during the estimating process by the bidders, drawn a special care on receipt, recording and assessment in the tendering process and Maintain a better communication during the tendering. These are the high ranked solution by the respondents as per the practical situation of the Sri Lankan construction industry. Thus, implementation of this strategy leads to achieve proper tendering process as well as successful projects.

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IMPACT OF SUSTAINABILITY EDUCATION ON QUANTITY SURVEYORS IN SRI LANKA

V.G. Shanika* and T.S. Jayawickrama

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Sustainability Education (SE) is recognised as a lifelong learning process aiming towards sustainable development which spreads beyond the limitations of formal education. In order to ensure proper commitment towards sustainable development through sustainable construction (SC) concept, quantity surveyor (QS) as a leading professional in the construction industry should go through a proper SE. Even though certain HEIs (Higher Education Institutions) in Sri Lanka have incorporated SE up to a certain extent into their curriculum, their effectiveness is questionable. Addressing this gap, the research analyses perceived importance, level of SE received and the effectiveness of SE of Sri Lankan QSs while identifying the knowledge areas where improvements are required. A comprehensive literature review was executed identifying knowledge areas to be included in SE of QSs globally. Through a survey of experts, 39 knowledge areas related to quantity surveying education were identified under six main categories considering the local context. Even though Relative Important Index (RII) values denoted that SE is substantially important to QSs, overall SE level of Sri Lankan QSs was found to be in 'moderate level'. QSs perceived their SE more on 'economic sustainability' as it exhibited the highest mean and RII values. Moreover, the results found that curriculum contribution to deliver SE is currently lower and QSs gain more knowledge on sustainability through industry practice than through formal education. The created matrix plot indicated that certain knowledge areas require further attention in curricula in HEIs which is revealed as the strategy that needs improvements.

Keywords: *Curriculum; Higher Education; Quantity Surveyor; Sustainability Education.*

1. INTRODUCTION

Despite the positive impacts that construction industry makes on a country's economy, it also has substantial negative effects on the natural environment (Xia et al., 2016). As per Ofori (2000), construction activities cause certain adverse environmental and social impacts and these impacts could be minimised through the concept of SC. The concept of SC is being adopted to align the construction industry with the sustainable development process (Murray & Cotgrave, 2009). SC considers three main domains namely environmental protection, social well-being and economic wealth (Tan et al., 2011).

In order to attain benefits through SC, construction professionals such as QSs, architects and engineers should have substantial knowledge and skills related to SC concept (Kwon et al, 2010). In this vein, increased recognition on SC has influenced to enhance the need for SE (Thomas & Nicita, 2002). As depicted by Wu and Shen (2016), "sustainability education", "education for sustainability", and "education for sustainable development" are interchangeable and synonymous terms in this field and this paper refers the term "sustainability education (SE)". As discussed by Wijesundara and Gunarathne (2012), construction professionals require SE to lead proactive actions towards SC and to apply specific knowledge and skills to take required actions and decisions together with self-motivation.

A research done by Ekundayo et al. (2012) for quantity surveying students in Northern University at United Kingdom (UK) indicated that there is a considerable sustainability related void in the quantity surveying

*Corresponding Author: E-mail – vgshanika9@gmail.com

education. In the Sri Lankan context, Samaratunga (2013) carried out a study intended to discover the relationship between the sustainable design practice and architectural education. The study concluded that there is a gap between architectural education on sustainability and the practice approaching Sri Lankan architectural students.

QS is one of the key professionals in the construction industry who adds value to the contractual and financial management of construction projects throughout the various stages (Hardie et al., 2005). As stated by Royal Institution of Chartered Surveyors, QSs can contribute to SC through lifecycle costing, alternative materials and technologies, renewable energy schemes, recycled content schemes, appropriate methods of supply chain management, value engineering and the ethical sourcing of materials and labour throughout the lifespan of the project (RICS, 2007). Therefore, considering the significant role played by quantity surveying professionals in promoting SC, it is essential for QSs to receive a proper SE in order to gain best outcomes through SC (Xia et al., 2016).

Since the Urban Development Authority in Sri Lanka, Green Building Council of Sri Lanka and the Ministry of Environmental and Natural Resources of Sri Lanka have directed their consideration towards sustainability, it is clear that there is an increasing trend towards sustainable development in Sri Lanka. In this vein, QSs involvement will be vital to achieve SC as a leading professional in the industry. Karunasena et al. (2016) identified the lack of education in SC concept as one of the significant barriers to implement SC in the Sri Lankan construction industry. Hence obtaining an effective SE has identified as essential for QSs.

Perera and Hewege (2016) mentioned that there is a strong positive relationship between incorporating sustainability in the curriculum and students' knowledge and understanding of sustainability through their study. Adegbile (2012) showed with a study in Nigeria, that there is a need to introduce sustainability related curriculum to higher education in architecture field to improve ability of providing sustainable design solutions within the built environment. Though certain construction related higher education programs have incorporated SE up to a certain extent into their curriculum, the effectiveness is questionable. Studies conducted focusing on the SE level of Sri Lankan QSs are lacking. Thus, the non-appearance of long standing viewpoint in literature and the need to identify the effectiveness of SE in Sri Lankan construction industry leads to a researchable gap in identifying impacts of SE on QSs in Sri Lanka. Addressing this gap, this study aimed to analyse the impact of SE on QSs in Sri Lanka.

2. LITERATURE REVIEW

Literature findings present about the concept of SE and knowledge areas that QSs should be educated in, which provide a platform to achieve objective one.

2.1. SUSTAINABILITY EDUCATION

The learning process on making decisions considering the ecology, economy and equity of entire communities in the long-term future is identified as SE (UNESCO, 2013). United Nations Education, Scientific and Cultural Organization (UNESCO) took the lead to approach towards sustainable development through the Decade of Education for Sustainable Development (DESD) (from 2005 to 2014) by integrating principles, values and practices of sustainable development into education and learning programs (UNESCO, 2013). Hence SE is considered to be essential to achieve sustainability.

SE has been identified as a vital element to affirm sustainable development by most of the HEIs around the world (Velazquez *et al.,* 2005). Several international declarations can be seen with the intention of providing guidelines and frameworks to HEIs to apply sustainability concepts into their systems (Lozano *et al*., 2013). Commencement with the Stockholm Declaration in 1972, a substantial development could be identified in international sustainability declarations applicable to higher education where many HEIs attempt to turn out to be more sustainable by signing these declarations (Wright, 2002).

Since the implications of SE vary among different disciplines, the various strategies can be adapted for educating, to suit with the nature of the discipline (Wijesundara & Gunarathne, 2012). It verifies that most of the findings in previous studies highlight four main education strategies in SE within higher education arena namely curriculum, research, campus operations and outreach. According to Uhl and Anderson (2001), the most effective way to attain SE by QSs is to gain adequate sustainability knowledge and skills through higher education before entering into the construction industry. Curriculum afford the highest contribution of student learning experience in higher education regarding sustainable development compared to other strategies (Hopkinson *et al.,* 2008).

Mazhar and Arain (2015) mentioned that there is an increasing demand for construction professionals who are competent with sustainable skill sets which would be critical to improve sustainability practices with the increasing complexity of the construction projects. Therefore, as future construction professionals, construction related students should have gone through proper SE during their higher education in order to build up knowledge, attitudes and competencies on SC (Kwon *et al.,* 2010). Thus, SE should be incorporated within construction related higher education programmes focusing on QSs as one of major construction professionals.

2.2. SUSTAINABILITY KNOWLEDGE AREAS RELATED TO QUANTITY SURVEYING EDUCATION

Quantity surveying professionals are experiencing changing roles in SC process where HEIs have the responsibility to develop their competencies and skills up to the required level (Thayaparan *et al.,* 2011). Furthermore, the competencies and skills required by a QS in performing SC have identified by various professional bodies such as Royal Institution of Charted Surveyors (RICS), Australian Institute of Quantity Surveyors (AIQS), Pacific Association of Quantity Surveyors (PAQS) and Institute of Quantity Surveyors Sri Lanka (IQSSL) (Yogeshwaran *et al.,* 2014). Beside the accountability for sustainability, SE has become a challenge for quantity surveying profession (RICS, 2012; Yogeshwaran *et al*., 2014). Hence, the requirement for SE for QSs is well-established.

Ekundayo *et al.* (2012) have developed a framework which includes knowledge areas to be included in QS education under six main categories. The framework has been developed capturing perceptions of university academic staff and industry professionals in UK (Ekundayo *et al.,* 2012). The same framework including 46 sustainability knowledge areas is also adapted by Tan *et al*. (2017) during their research which has focused on quantity surveying students in UK universities. Xia *et al*. (2016) also found a set of knowledge areas in SE of quantity surveying professionals, through a case study of Queensland University of Technology (QUT) quantity surveying course in Australia. Also, they categorised knowledge areas under environmental, economic and social sustainability pillars and their findings denote that environmental and economic sustainability were more visible than social sustainability (Xia *et al*., 2016).

Altogether Literature review identified 56 knowledge areas related to SE of QSs under six main categories namely; Background knowledge and concept, Policies and regulations, Environmental issues, Social issues, Economic issues and Technology and innovation which were presented by Ekundayo *et al.* (2012) and Xia *et al.* (2016) and also supported in a study by Tan *et al.* (2017) and further warranted by several other studies such as Ofori (2000), Ogunbiyi *et al*. (2013), Pitt *et al*. (2013) and Verster (2005).

3. METHODOLOGY

After the comprehensive literature review which identified 56 sustainability knowledge areas that QSs should be educated in, a survey of experts was conducted in the form of semi structured interviews with three experts in the field of quantity surveying selected using purposive sampling. They have substantial experience in the industry and/or academia for more than 20 years. The experts were asked two main questions; first to validate and refine SE knowledge areas identified through the literature considering their relevance to Sri Lankan context and as the second question to identify most appropriate category for the SE knowledge areas which are commonly identified under two or more categories in literature review and finally the outcome was used to develop a questionnaire.

Respondents of questionnaire survey had to indicate strategies by which SE is obtained, the perceived importance and SE level considering each knowledge area. The questionnaire was distributed among Sri Lankan QSs adapting convenience sampling which is a non-probability sampling technique.

The importance of each identified knowledge area in the role of QS were analysed with regard to categories, by ranking categories with their Relative Importance Index (RII) values using below equation.

$$RII = \frac{\sum_{i=1}^{n} Wi}{A \times N} \qquad \text{Eq. (01)}$$

Where, W=Constant expressing the weighting given to each response, A=The highest weighting, n=The frequency of responses, N=Total number in the responses

Mean Weighted Rating (MWR) values of each category were compared to analyze the SE level of Sri Lankan QSs using below equation.

$$MWR = \frac{\sum_{i=1}^{n} Wi}{N} \qquad \text{Eq (02)}$$

Where, W=Constant expressing the weighting given to each response, n=The frequency of responses, N=Total number in the responses

Importance Performance Analysis (IPA) Matrix was adapted to determine the effectiveness of SE of Sri Lankan QSs using the data collected through the questionnaire. The IPA matrix consists a pair of coordinate axis in which 'y' axis denotes the 'importance' while the 'x' axis depicts the 'performance'. In the matrix created in this study 'x' axis was identified as SE level while 'y' represented the importance of each knowledge area in the role of QS. Hence the effectiveness of SE could evaluate by analysing the matrix illustrated in Figure 3 where 'Quadrant I' denotes the highest effectiveness while 'Quadrant II' was given more concern as it includes knowledge areas that improvements should be made in quantity surveying education

4. DATA ANALYSIS AND FINDINGS

Through expert validation, 39 knowledge areas were determined as relevant within the Sri Lankan context as presented in the Table 1, and considered for further analysis. Moreover, the categorization of knowledge areas identified within the literature was also validated considering the Sri Lankan context with the usage of expert views. The knowledge areas identified as common under two or more categories were given most appropriate category considering the expert opinion. All 39 knowledge areas were categorised under six main categories namely Background knowledge and concept, Policies and regulations, Environmental sustainability, Social sustainability, Economic sustainability and Technology and innovation.

Table 1: Knowledge Areas for SE of QSs - Findings of Survey of Experts

Category/ Knowledge areas	
A. Background knowledge and concept	**D. Social sustainability**
A1. Sustainable development overview and principles A2. Impact of the construction industry on the environment A3. Sustainable construction concept and strategy A4. Role of QS in sustainable development	D1. Corporate Social Responsibility (CSR) D2. Individual sustainability/ morale D3. Cost Benefit Analysis D4. Ethical issues such as ethical sourcing of materials and labour, for instance D5. Health and safety
B. Policies and regulations	**E. Economic sustainability**
B1. Building regulations related to sustainability B2. Energy Performance certificates B3. International conventions and treaties B4. Planning and regulation act B5. Environmental act	E1. Cost planning and management E2. Value management or engineering E3. Sustainable procurement strategies E4. Feasibility studies E5. Whole-life appraisal/ Life cycle costing E6. Sustainable project management practices E7. Sustainable facility management practices E8. Environmental economics
C. Environmental sustainability	**F. Technology and innovation**
C1. Protecting and enhancing the built and natural environments C2. Environment Impact Assessments (EIA) C3. Environmental Management Systems; ISO 14001 C4. Environmental Assessment Methods; BREEAM, LEED	F1. Professional and management software packages such as BIM, etc. F2. Modern methods of construction F3. Supply chain management F4. Effective information control and management (using e-business)

Category/ Knowledge areas
C5. Reducing energy consumption and greenhouse gases
C6. Carbon Agenda
C7. Sustainable transport
C8. Sustainable building practices
C9. Green building materials
C10. Sustainable and efficient energy
C11. Sustainable building services
C12. Raw materials usage trend
C13. Waste reduction principles

Questionnaires were distributed among 97 QSs who are currently practicing in the Sri Lankan construction industry and 69 were responded resulting a response rate of 71.13%. Demographic characteristics of the 69 respondents are elaborated in Table 2. Considering the number of higher education institutes offer QS education in Sri Lanka, and the QSs available in Sri Lanka, this can be considered as a representative sample.

Table 2: Demographic Characteristics Questionnaire Respondents

Variable	Categories	Frequency	Percentage
Type of organization	Contractor	27	39%
	Consultant	29	42%
	Client	13	19%
Experience as a QS	1-10	34	49%
	10-20	24	35%
	More than 20	11	16%
Type of higher education received	BSc - Local	39	57%
	BSc – (Local in collaboration with International Institutions)	16	23%
	Diploma	14	20%

4.1. *IMPORTANCE OF SUSTAINABILITY EDUCATION*

The perception of the respondents about the importance of each knowledge area to the role of QS were measured. They were asked to indicate the level of importance using a five points scale (1 - "Not important", 2 - "Little important", 3 - "Somewhat important", 4 - "Important" and 5 - "Highly important"). The relative importance of each knowledge area was calculated using RII and importance of each category is presented in Figure 1.

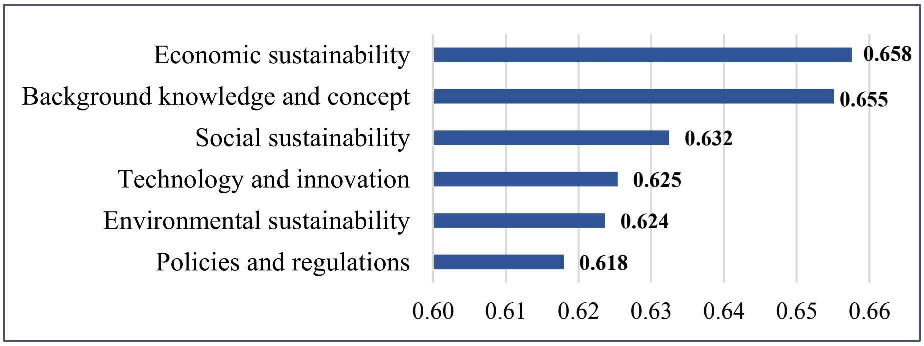

Figure 1: RII Value for Importance Based on Categories

Figure 1 indicates that category E - 'Economic sustainability' and category A – 'Background knowledge and concept' have substantial relative importance than the other four categories and 'Economic sustainability' driven to the top denoting the highest RII value of 0.658. 'Policies and regulations' reported the lowest RII value of 0.618.

4.2. SUSTAINABILITY EDUCATION LEVEL

The respondents were asked to indicate the level of SE they gained in a five points scale (1- "Not educated", 2- "Little educated", 3- "Somewhat educated", 4- "educated" and 5- "Highly educated"). Figure 2 demonstrates the MWR value of each category with regard to the SE level of the Sri Lankan QSs.

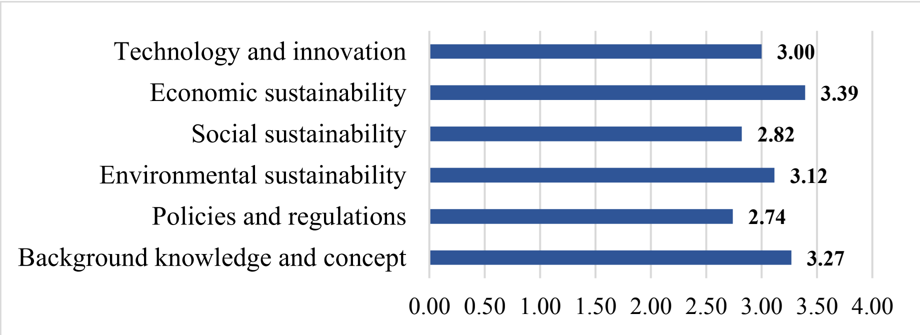

Figure 2: MWR Value for SE Level Based on Categories

QSs in Sri Lanka denote the highest education level within the Category E- 'Economic sustainability' with MWR value of 3.39. When three pillars of SC are considered within SE of Sri Lankan QSs, the priority order from highest to lowest varies as economic, environment and social. The overall SE level was calculated as 3.09 by taking the average of MWR values from all categories where overall SE level of QSs can be considered as 'moderate level'.

4.3. EFFECTIVENESS OF CURRENT SUSTAINABILITY EDUCATION

Although there are important knowledge areas to the role of QS, the SE level is yet to be questionable. Hence, in order to seek on the effectiveness of SE received by QSs, IPA matrix was created scattering the MWR values of perceived importance and SE level of each knowledge area. Quadrants were formed using the neutral values in the two scales where both are having 3.00 as the middle value in the five-scale considered. IPA Matrix was illustrated in Figure 3.

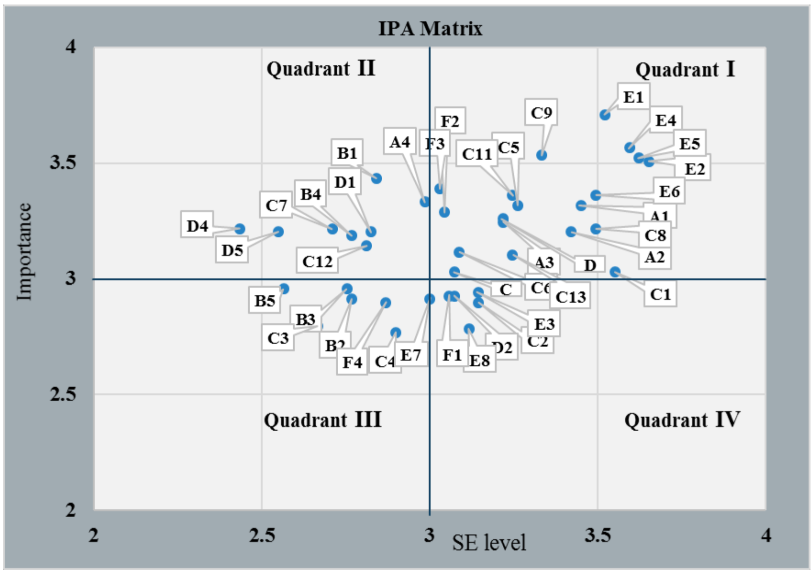

Figure 3: Matrix Plot for Importance vs SE Level

Quadrant I denotes the SE knowledge areas with highest SE level and highest level of importance in which displaying the highest effectiveness in the SE (keep up with the good work). The Quadrant II is consisting with knowledge areas with higher importance but, lower SE levels are received (area for improvement). Quadrant III represents the knowledge areas with lower education level and lower importance where lower priority can be given. Knowledge areas with higher SE level and lower importance are given in the Quadrant IV (possible overkill). Hence knowledge areas in Quadrant I and II need to be focused.

Quadrant I includes 19 knowledge areas and these effective knowledge areas should be continuously adapted within the curriculum. Further, eight knowledge areas that require improvements in the incorporation to formal education are identified in the Quadrant II.

Sustainability Education Strategies

The composition of SE strategies illustrating in which ways respondents have obtained SE, are denoted in Figure 4.

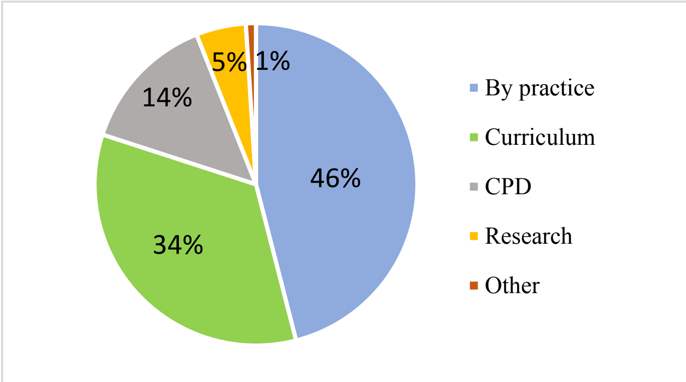

Figure 4: Composition of SE Strategies

It can be noted in Figure 4 that the majority of the respondents (60% - combining 'By practice' and 'CPD') have gained SE during practice in the industry. Only 39% of respondents (combining 'Curriculum' and 'Research') have gained SE through formal education. Some of the 'other strategies' mentioned by the respondents are symposiums and courses which address the given sustainability aspects within the quantity surveying education. Thus, the results depict that the contribution of the curriculum to SE is substantially lesser than the SE gained through the practice.

The Detail Evaluation of Sustainable Strategies in Knowledge Areas of Quadrant I and II

Since there are different strategies, Quadrant I and II were further analysed based on two main strategies 'By practice' and 'Curriculum' as presented in Figure 5.

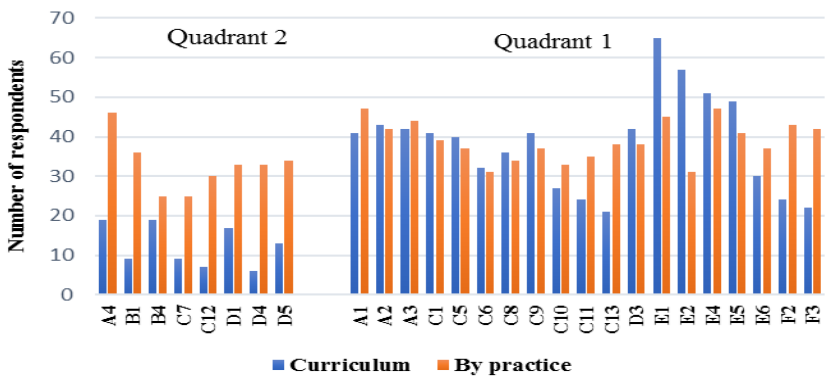

Figure 5: 'Curriculum' and 'By Practice' Comparison of Quadrant I and II

It can be noted that the values under the industry practice and curriculum are almost similar in the knowledge areas in the Quadrant I. Moreover, the SE gained through the curriculum is substantially higher in the Quadrant I when compared with Quadrant II. A massive gap can be seen between curriculum and practice within the knowledge areas in Quadrant II. Since Quadrant II depicts a lower SE level apart from higher importance of those knowledge areas, the less curriculum contribution can be the reason behind. It reveals that knowledge areas with lower SE level have less contribution from curriculum but obtained mainly by practice.

Since QSs can gain knowledge through practice over the time, the analysis was carried out to seek the impact of level of experience of respondents on the SE level as illustrated in Figure 6. As expected, it can be noted in Figure 6 that more experienced QSs have gained higher SE level. The reason could be that more experience denotes more industry practice within the role of the QS. So further analysis was done considering 'Curriculum' and 'By practice' contribution to SE level with regard to experience level as shown in Figure 7.

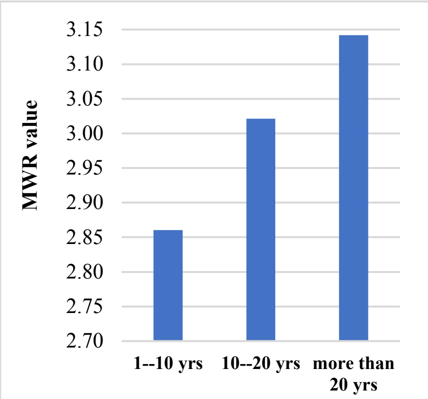

Figure 6: SE Level based on Level of Experience

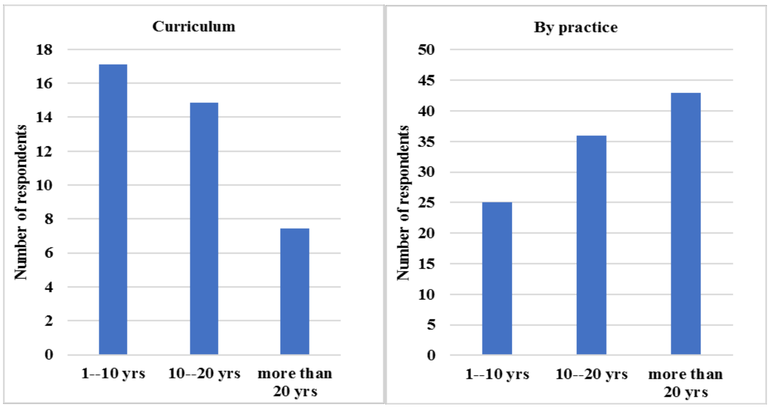

Figure 7: Curriculum' and 'By Practice' Contribution as per the Experience Level

As expected, most of the QSs with higher experience level have gained SE more through industry practice. Referring to Figure 7, the behaviour of the 'number of respondents educated through curriculum' is solely opposite with 'number of respondents who gained education through practice' related to their experience level. Hence the results imply that the quantity surveying curriculum has been increasingly incorporated SE within its content in the near present than in the past. Therefore, incorporation of SE to curriculum has increased over the time but there are knowledge areas which are important but yet to be improved and to be incorporated to formal education through curriculum.

5. DISCUSSION

As explained in the Introduction Section, Karunasena et al. (2016) highlighted lack of education in SC concept as one of the significant barriers to implement SC in Sri Lankan construction industry. Since the findings elaborated that Sri Lankan QSs are having a 'moderate SE' level, the findings seem to be still supporting the literature up to certain extent.

Referring to Sub Section 2.2, in a study which has done for quantity surveying students in UK, the level of quantity surveying students' knowledge had been evaluated (Tan et al., 2017). When the results of that study were compared with the findings of current study, it can be noted that the priority of incorporating three pillars is entirely same in both studies in UK and Sri Lanka as economic being the highest and then environmental and social. Further 'Policies and regulations' is least addressed within the quantity surveying curriculum of UK and Sri Lanka.

Referring to Sub Section 2.2, due to less visibility of knowledge areas on social sustainability in QUT quantity surveying course, the requirement to incorporate social knowledge areas has been emphasised (Xia et al., 2016). Samaratunga (2013) concluded in her study (Refer Introduction Section) that Sri Lankan architects more perceived towards environmental sustainability within their education, where this study denoted Sri Lankan QSs are more perceived towards economic sustainability among the three pillars economic, social and environment. Hence incorporating economic pillar more in the QS education is reasonable.

Results show that curriculum contribution is identified as insufficient with regard to quantity surveying education in Sri Lanka. Referring to Sub Section 2.1, curriculum afford the highest contribution of student learning experience in SE compared to other strategies in United Kingdom (Hopkinson et al., 2008). Hence curriculum incorporation within the education of Sri Lankan QSs is required to be upgraded.

6. CONCLUSIONS

The research findings revealed that SE has a substantial importance to the role of a QS. Moreover 'economic aspects' are perceived more importance within the role of a QS. The overall SE level of Sri Lankan QSs lies in the 'moderate level'. However, current SE for Sri Lankan QSs have focused more on economic perspectives overcoming other two pillars; social and environmental. The reason could be the given perspective of economics of construction which is crucial for QSs.

Among different strategies that QSs have gained SE, Sri Lankan QSs have gained SE mainly 'by practice'. Although incorporation of sustainability knowledge areas within the quantity surveying curriculum shows a gradual development over the time, it is yet to be improved in several areas as identified with a gap between importance and level of SE received.

The study highlights the SE level and the effectiveness of SE gained by Sri Lankan QSs. The findings proved that the most effective knowledge areas tend towards 'economic sustainability'. It is found that further improvements should be made focusing the curriculum of HEIs as suggested through the study. It supports the view highlighted by scholars in the global context that more focus should be given to curriculum improvements in higher education related to the key professionals in the industry in achieving sustainable construction goals in a country (Adegbile, 2012; Perera and Hewege, 2016). Further education level on effective knowledge areas should be maintained and can also improve within HEIs. Thus, SE need to be improved among QSs in Sri Lanka.

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IMPACT OF USING MINIMUM PRELIMINARY ITEMS FOR BUILDING WORKS IN SRI LANKAN CONSTRUCTION INDUSTRY

P.G.C. Pradeep*, L.D. Indunil P. Seneviratne, Uthpala Rathnayake and D.G. Melagoda

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Preliminary items section is one of the critical sections in a bill of quantities, though they are not direct parts of the permanent work. There are some preliminary items which are not included in the preliminary bill. In Sri Lankan construction industry employers are willing to pay for the preliminary items which mostly impact to the work items while ignoring the other items. Further, corporate consultants do not instigate employers to include preliminary items. There is a research gap in identifying the impact of minimum usage of preliminary items for building works. Hence, this research was aimed at investigating the impact of using non-detailed preliminary bill for building projects in Sri Lanka. Initially, a literature synthesis was carried out to identify the preliminary items commonly included in the preliminary bill for the building projects in locally and in global context. Furthermore, factors to be considered when pricing the preliminary bill and the importance of preliminary items were identified. Subsequently, the relationship between preliminary amount and the total contract amount was recognized. Data was collected through the semi structured expert interviews and a work study. Thirty building projects were selected for the work study. The collected data was analysed using content analysis with the use of Nvivo 11 software. The analysis revealed that there are negative impacts due to minimum usage of preliminary items in the preliminary bill such as; deterioration of standard and quality of the construction industry, lack of investments toward construction industry, impact to the employer and subsidence of involvement of labours in the construction industry name to few. Furthermore, the paper discussed the factors to be considered when preparing the preliminary bill. Among those factors size of the project is a critical factor when preparing the preliminary bill. Moreover, findings disclosed that average preliminary percentage of building projects is 4.98% and the percentage is increasing with the accretion of the contract amount in Sri Lankan construction industry.

Keywords: *Building Projects; CIDA Standard Bill; Construction Industry; Preliminary Bill.*

1. INTRODUCTION

The most difficult items to price in a Bill of Quantity (BOQ) are often termed as Preliminaries Bill or Bill No 1. This section is not confined to any particular work section, and the contractor is thereby given the opportunity to price those (Jimoh & Adama, 2011). According to Perera et al. (2009), insufficient estimation is a risk mainly because price escalation had not been considered for recurrent preliminary items. Habitually companies will use typical preliminaries as the basis of preparing the preliminary bill to reduce the drafting time and force the quantity surveyor to continually question the need of a particular item (Lee et al., 2014). As mentioned by Inyang-Udoh (2013), the percentage varies from 4.5% for a specialist organization tendering for a large new project to 9.5% for a new housing project. Many disputes concerning the valuation of variation and the final account could be resolved more easily if an accurate and consistent set of comprehensive preliminaries is available (Ostrowski, 2013).

Thus, this paper aims at reviewing the impact of using minimum preliminary items for building works in Sri Lankan construction industry. The first few sections of the paper present the comprehensive literature review findings while the last sections present the findings of semi structured interviews conducted with construction industry professionals and the work study.

*Corresponding Author: E-mail – pgchinthaka12@gmail.com

2. LITERATURE REVIEW

2.1. *PRELIMINARIES*

The preliminaries section in a BOQ is generally priced by the tenderers independently from trade or elemental bills (The Entrusty Group, 2009). The bill of quantities rate cannot reasonably cover all costs required for the implementation of a construction project due to the general nature of the items; these items are covered under the concept of preliminaries (Odusami & Oni, 2007). Preliminaries are vital for reaching project objectives (Jimoh & Adama, 2011). "Preliminaries are the cost of administering a project and providing plant, site staff, facilities site-based services, and other items not included in the rates for measured works" (RICS, 2012). According to Ghani (2006) insurance, workmen's compensation, performance bond, setting out, Construction Industry Development Board (payment for levy), as-built drawing, work programmes, hoarding and fencing, Client/Employer's requirements such as vehicles for the site office and equipment and facilities are mandatory preliminary items.

2.2. *PRICING PRELIMINARIES*

Estimators and those who are involving in pricing of BOQs should properly educated and exposed in the pricing of preliminaries with a view to pricing all the relevant components and items in the preliminaries bills (Inyang-Udoh, 2013). According to Ghani (2006), all preliminary items are not required to be priced, some items can remain without pricing. It is seen by the majority of clients as being fair and likely to produce the lowest possible commercially viable tender price in the prevailing market conditions (Harris & Mc Caffer, 1989). It is a common practice for appointed technical professionals advising their clients to assign the responsibility for providing the preliminaries components to the Contractors (Singh, 2008).

Preliminaries are crucial and constitute part of the contractor's profit margin consideration (Abas et al., 2017). Further to them, under limited time frame, some contractors refer back to a previously priced set of preliminaries of similar project and then extract the price for use in the current project for tender. The preliminaries section needs utmost care in pricing as it is the section which covers the cost of operating the site under specified conditions and in accordance with the contractor's plan for the progress of the work and for storage and movement of materials, plants and site establishment in contractor's estimate (Ross et al., 1991). Willis (2005) identified that, when pricing preliminaries, there should be a clear understanding to determine the extent of this allowance when tendering preliminaries and general items of its scope and broad definition, as it can easily contribute to huge losses if not correctly understood or determined at the tender stage. Brook (2008) identified preliminaries are usually unique to a particular job and should be calculated whenever there is deviation from an identical scheme and it is a problem which need to be recognized when advising clients. Most of the contractors priced the bill of preliminaries rather than insert lump sum or percentage of the cost of the project (Inyang-Udoh, 2013) even though all the preliminaries items listed in the tender are deemed to be priced by the contractor in accordance with the principle of standard method of measurement of building works (Morledge & Kings, 2006). According to Morledge and Kings (2006), the way contractor pricing the preliminaries imitate the contractor's tendering strategy.

2.3. *PRICING PRELIMINARIES*

The items in the preliminaries section of the bills of quantities are usually the most difficult and arbitrary of all to price (Bello & Adetayo, 2013). Pricing of the preliminaries section will usually be one of the last operations before adjudication of the tender price, and will require that decisions relating to working methods, major plant, gang strengths, subcontractors, and temporary work (Ghani, 2006). It is important to discover the extent to which preliminary items are priced (Ashworth, 2010). Haruna et al. (n.d.), identified methods of pricing project's preliminaries as contractors used percentage ratio, contractors employed fixed charge (lump sum) and estimation methods, contract sum as amount of preliminary cost of a project. According to Inyang-Udoh (2013) percentage approach can be disposed to risk for inexperience contractors who lack an understanding of the cost involved. The lump sum pricing in preliminaries is awkward to estimate because some of the items under preliminaries are time related and others are work related. Therefore, if they are not separately priced, consultant could not be to carry out realistic estimation of preliminaries (Jagboro, 1989). Provisional sums inserted in the preliminaries bill cause a great deal of confusion (Brook, 2008). Preliminaries are part of overhead, other than contractors head office overhead, therefore mark-up included in the rates of measured works in BOQ shall not include expenses in relation to items include under preliminary items (Institute for Construction Training and development, 2009). According to the methods identified by Trevor Sadd Associates (2005), in most cases the analysis proposed in methods one to three can be simply achieved by setting pricing out in added columns on the check list while using percentage approach requires a significant amount of judgement.

2.4. *COST OF PRELIMINARIES*

The cost of preliminaries varies between contractors depending on the complexity of projects (Abas et al., 2017). There is an impact on the resources required for the project, they affect the pricing of preliminaries including site overheads and general overheads (Akintoye, 2000). Cost of preliminaries is between five and fifteen percentage of the overall cost of contract value in respect of building construction costs (Jimoh & Adama, 2011). According to the study of Abas et al. (2017) the preliminaries of civil infrastructure works are between 3.26% and 6.38% as compared to that of building works between 3.60% and 7.94%. Consequently, the preliminaries of civil infrastructure work are lower up to 16.5% as compared to the building work. Further to the author typical preliminaries are higher than 3% but not exceeding 10% of the tender sum for both types of construction works. The cost of 'Preliminaries' has been detected to be between 5%-15% of the overall cost of 'Contract' value in respect of building construction costs while for infrastructure the percentage could be between 2%-5% (Singh, 2008). Brook (2008) identified range of preliminaries suitable for market sectors as shown in Table 1.

Table 1: Preliminary Percentage by Sector

Sector	Preliminaries cost out of net build cost
PFI Hospitals	17-19%
BsF Schools	14-17%
MOD prime contracts	16-22%
Large warehouse	8-11%

Source: (Brook, 2008)

2.5. *BENEFITS OF HAVING A GUIDELINES FOR PREPARING PRELIMINARY BILL*

As a result of the subjective nature of preliminaries pricing, its pattern of pricing varies considerably between different contractors (Peurifoy & Oberlender, 2002). Ghani (2006) stated that if all the tenderers' priced BOQ for any project could be observed, this preliminaries section would produce the highest variation in prices with each estimator having his own idea as to the scale and extent of the costs involved. Haruna et al. (n.d) mentioned that if the actual project's preliminaries are below the estimation stated in Bill of Quantities, then it will become the contractor's profit and if the actual project's preliminaries are higher than the estimation, then it will become the contractor's loss. There is a guideline which was published by CIDA for preparing preliminary bill to the employer or consultant in Sri Lanka. If there is a guideline for preparing preliminary bill it is easy to identify the items need to be include in the preliminary. According to Normah, (as cited in Haruna et al., n.d) clients has to face many challenges during the tender evaluation especially on cost comparison for preliminaries of each tenderer. Further to the author distinguishing and understanding items needed to be priced for a given project, contractor to effectively calculate and evaluate the preliminaries of bill of quantities of building projects and achieve effective price for the project preliminaries.

3. RESEARCH METHOD

A comprehensive literature survey was carried out to identify the research gap and theoretical condition on impact of not including relevant preliminary items in preliminary bill according to the CIDA standard bill of preparing preliminary bill referring journals, books, articles, conference proceedings and reports. Mixed method approach was adopted in this study to full fill the research objectives. Preliminary interviews with two experts with more than 10 years experiences in consultant quantity surveying were conducted to validate the findings in literature survey. Further seven (07) semi structured interviews with quantity surveying experts who have involved in preparing preliminary bills were conducted to identify the preliminary items which are not included in preliminary bill and reasons for not including them. Furthermore, a work study was conducted in 40 projects to identify the commonly used preliminary items in the building construction projects in Sri Lanka and contribution of preliminary bill to the total cost of the building. The qualitative data gathered were analysed using content analysis technique and the quantitative data gathered were analysed through Microsoft Excel 2016. Mean value and standard deviation were calculated for finding the preliminary percentage for the government and private projects with contract sum over 300 million and contract sum below 300 million. Further percentage of preliminary items included in preliminary bill comparing to the CIDA standard bill was analysed using Microsoft Excel 2016.

4. RESEARCH FINDINGS

4.1. REASONS FOR MINIMUM USE OF PRELIMINARY ITEMS

The current practice of Sri Lankan construction industry is providing a minimum enumerated preliminary bill for building projects. Most of the times consultants advice to include a preliminary bill with the lesser number of preliminary items as an individual client does not like to accept a huge preliminary bill as it is an indirect cost. Clients' idea is that preliminaries are an unnecessary and extra cost for them. They questioned why they should pay for those items since those are indirect costs. Further contractors price the preliminary bill, and the main bill without considering the preliminary bill. All the costs relating to the preliminary items are included in the preliminary bill. This practice is mainly identified with the lower level contractors. They do not itemise the preliminary bill and do not break down the rates. Therefore, whether a detailed preliminary bill included or not, the rates of main trade works are equal. Therefore, consultants are alluded to use minim um preliminary itemised bill.

4.2. INCLUSION OF PRELIMINARY ITEMS

In Sri Lanka CIDA standard bill can be considered as the base of a preliminary bill. The inclusion of preliminary items mentioned in CIDA bill was compared within 40 projects selected. There are forty preliminary items in CIDA standard preliminary bill as depicted in Table 2.

Table 2: Preliminary Items Included in CIDA Standard Preliminary Bill

No	Description
	Insurance and securities
1	Provisional sum for providing a Performance Security
2	Provisional sum for providing an Advance Payment Security
3	Provisional sum for insurance of Works, Machinery & Equipment, Plant, Materials, third party persons & property and Employer's personnel & property at site as per Contract.
4	Provisional sum for insurance against accidents and injury to Contractor's personnel as per the Contract.
	Engineer's Facilities
5	Allow lump sum for constructing maintaining dismantling and removal on completion of the works, a temporary building for Engineer's office in conformity with the plans provided for Engineer's requirements, including necessary furniture and fittings, furnishing, sanitary facilities and other facilities
6	Allow lump sum for providing telephone, internet, e-mail and facsimile facilities, electricity and water services for the Engineer's site office for their use in connection with the Works.
7	Allow lump sum for maintenance, rental, consumption charges for telephone, facsimile facilities, electricity and water services Engineer's site office for their use in connection with the Works.
	Contractor's Facilities
8	Allow lump sum for constructing, maintaining, dismantling and removal on completion of the Works, a temporary site office with facilities.
9	Allow lump sum for constructing, maintaining, dismantling and removal on completion of the Works, buildings to be used as workshops and stores for perishable materials.
10	Allow lump sum for constructing, maintaining. Dismantling and removal of completion of Works temporary buildings in accordance with the plans prepared by the Contractor and occurred by the Engineer to accommodate the following

No	Description
	▪ Workers' rest rooms ▪ Toilets and wash areas ▪ Sick/First Aid rooms ▪ Accommodation for contractor staff and workmen including sanitary facilities on site is applicable. ▪ Facilities to workmen shall conform to the latest public health and industrial regulations.
11	Allow lumps for providing accommodation including sanitary facilities and transport for contractor's staff and workmen offsite
12	Allow lump sum for providing telephone and facsimile facilities, electricity and water services for the Contractor's site office for their use in connection with the Works
13	Allow lump sum for maintenance, rental, consumption charges etc. for telephone and facsimile facilities, electricity and water services for the Contractor's site office for their use in connection with the Works
14	Allow lump sum for Contractor's transport facilities at site
	Construction Management and Supervision
15	Allow lump sum for employing suitably qualified and experienced technical personnel on full time basis for construction management services at the site
16	Allow lump sum for employing technical supervisory staff not listed under item 16 above on full time basis. Listed below are the particulars of staff to be engaged.
	Setting Out
17	Allow lump sum for employing a licenced land surveyor to define the building site work etc.
18	Allow lump sum for setting out of works in accordance with drawings and other written information given by the engineer
	Quality standards and Progress
19	Allow lump sum for provision of progress reports including photographic records and other schedules included in the ICTAD publication. Guidelines for Effective Construction Management.(ICTAD/CM/), relevant to contract administration as directed by the Engineer.
20	Allow lump sum for all cost in connection with preparing samples for testing, making arrangements for testing of Materials, Goods etc., as stipulated in the specification, obtaining test reports and submitting the same to the Engineer
21	Allow lump sum for provision of drawings, bar schedules etc. for Engineer's approval
22	Allow lump sum for provision of two sets of (hard copies and soft copies) as-built drawing of all services, for engineer's approval
	Health safety and Environment
23	Allow lump sum for engaging the service of an adequately trained person to attend to first aid medical duties including provision of a first-aid box and regular supply of medicine, linen etc.
24	Allow lump sum for providing and maintaining a first aid box supply of medicine, linen etc.
25	Allow lump sum a. Employing workmen to clean and maintain all areas to be in good hygienic conditions including toilets, wash areas, kitchen etc. b. Supplying adequate drinking water, water for washing purposes, soap, detergent, etc. throughout the period of construction
26	Allow lump sum for providing all necessary safety measures to workmen at site conforming to the latest industrial safety regulations and as directed by the Engineer
27	Allow lump sum for making adequate provisions against air and noise pollution of surrounding areas. Hoarding and dust screens shall be provided to control dust escaping to surrounding areas
28	Allow lump sum for maintaining the site in a clean orderly in manner at all times and during the entire contract period
29	Allow lump sum for demobilization, removal of all rubbish and debris and clearing up site on completion, leading all in good order and handing over
	Security and Protection
30	Allow lump sum for employing an adequate number of security personnel and security systems on full time basis throughout the period of construction, and provide for necessary security lighting and a warning system.
31	Allow lump sum for providing and maintaining necessary fencing, boarding and gates for safeguarding the works, materials and plant, as directed by the Engineer

No	Description
32	Allow lump sum for protection of public and private service at the site. The Contractor shall take due care to protect, water supply and drainage systems, telephone and overhead electrical cables etc. whose locations are identified and made available to bidder at the time of bidding, unless earmarked for demolition, during the execution of the works.
	Services and Facilities
33	Allow lump sum for supply of water for the Works and paying all charges and other expenses in connection with the supply from water mains or any other alternative method of water supply, storage and reticulation
34	Allow lump sum for supplying temporary electricity for the Works including connection, distribution system for the Works, internal arrangements and all payments to the authorities for consumption
35	Allow lump sum for providing hoisting equipment and other plant for the use of the works on site(dry hire)
36	Allow lump sum for providing small machinery and equipment for the use of the Works at site
37	Allow lump sum for erecting and maintaining scaffolding and/ or self-climbing platforms. Such scaffolding etc. shall be removed on completion and all Works disturbed shall be made good
	Miscellaneous
38	Allow lump sum for stamp duty in accordance with the prevailing regulations of the Government.
39	Allow lump sum for providing and maintaining a name board to the specifications and / or as directed by the Engineer.
40	Allow lump sum for excavation for trial pits/ trial trenches as specified or as directed by Engineer as for locating services etc. and reinstating the ground and making good disturbed work to the satisfaction of the Engineer.

The frequency of usage of preliminary items were calculated for the selected 40 building projects comparing to CIDA standard bill. After analysing the information obtained from work study, it can be identified the items that are mostly included when preparing the preliminary bill and the items which are minimally included in preliminary bill. The percentage of each preliminary item was ranked with reference to CIDA standard bill as in Figure 1.

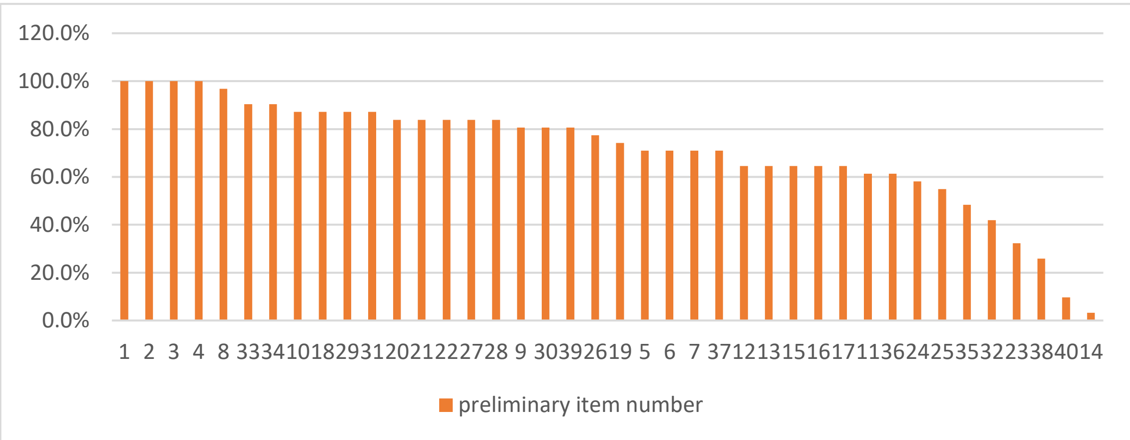

Figure 1: Ranking of Preliminary Items

When examining the percentage of each preliminary item, items under the insurance and securities had the highest percentage. All the building projects selected included items for insurance and securities. It revealed that insurance and securities is the most important item in preparing the preliminary bill. Second highest percentage taken for the constructing of contractors site office. 96.8% of the selected projects included this item in their preliminary bill. The next most included item is supply of water and temporary electricity for the works. These are essential services that should be provided. Therefore, it is clarified in this study that 90.3% of projects included these items. 87.1% of the selected projects had included preliminary items for accommodation and restrooms toilet facilities. Further same percentage was included for setting out of works, clearing up site on completion and providing and maintaining necessary fencing and boarding for the safeguarding the works. It was revealed that these items are basic needs that should be included in preliminary bill. The next highest percentage of included the preliminary items are quality standard, progress and preliminary items regarding protecting the environment. It is disclosed that significance proportion for quality standards and protecting environment were provided in the preliminary bill. 80.6% selected projects included items for constructing stores, workshops and providing security personnel and security systems. Further same percentage was included for providing and maintaining a name board. 77.4% of selected projects had included items for providing safety measures for the workmen at site. 71.0% of selected projects had included engineer's facilities while 64.5% included for contractor's facilities. But other facilities such as telephone, facsimile facilities workmen accommodation have included in their trade rates. Only 61.3% of the selected projects had included provisions for small plant and machineries. The preliminary item for providing a first aid box included only 58.1% of the selected project. Providing trained person for health and first aid facilities is not considered here. Because it is also covered under this item. The percentage will be increase if those two items considered as one item. Almost half of the selected project included the item for clean and maintain all areas to be in good hygienic conditions including toilets, wash areas, kitchen.

Further only 48.4% was included an item for providing hoisting equipment and other plant. It revealed that hoisting equipment are used only for particular projects. Furthermore, only few projects had included item for protection of public and private service at the site. It is confirmed that the opinion of expert survey, that it would be a reason for arising disputes by including this item. Another least included item compared to CIDA standard bill was providing an adequately trained person to attend to first aid medical duties including provision of a first-aid box. Only 32.3% had included this item. Excavation for trial pits/ trial trenches were 2nd least item included in the selected projects while least item included in the selected projects was contractor's transport facilities at site.

When inclusion of preliminary item compared to the CIDA standard bill considered separately according to the categories of over 300 million projects (OTM), below 300 million projects (LTM), government projects (GOV) and private sector projects (PVT). Comparison of inclusion of preliminary item according to the category is graphed as Figure 2.

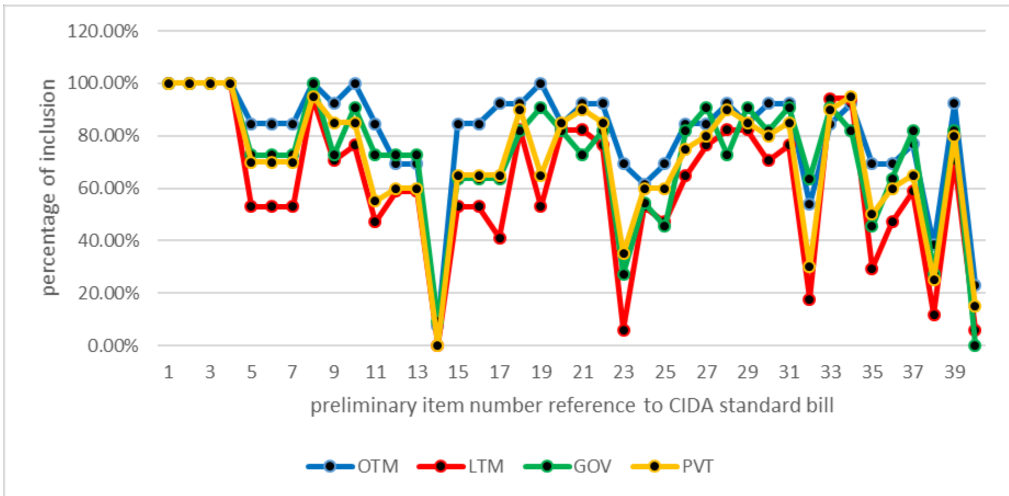

Figure 2: Comparison of Inclusion of Preliminary Item According to the Category

According to the analysed data it can be detected that percentage of inclusion of preliminary items for government projects and private projects are almost same pattern in the graph but slight differences are in some. Such as item of provision for progress reports including photographic records and other schedules. Percentage is much higher in government project than in private projects. Further providing accommodation including sanitary facilities and transport for contractor's staff and workmen offsite has slight difference in those two categories. The percentage is higher in government than in private projects. Comparing to the projects which contract sum over the 300 million and contract sum below the 300 million, the pattern of the graph is almost same. Moreover, it was revealed that size of the project is obviously affect in the preparing preliminary bill. Further, the detailed preliminary bill is used for the large scale projects. There is a huge difference in some preliminary items such as providing engineer's facilities, providing accommodation including sanitary facilities, construction management and supervision, employing a licensed land surveyor to define the building site work and engaging the service of an adequately trained person to attend to first aid medical duties including provision of a first-aid box. These mentioned preliminary items involve higher cost according to the opinion of expert professionals and individual client cannot bear that cost. That would be a cause for higher percentage in large scale projects and lower percentage in small scale projects.

4.3. CONTRIBUTION OF PRELIMINARIES

The data gathered through work study was analysed illustrated in a graph according to the categorisation of large scale and small scale building projects. Forty (40) buildings projects were selected for analysing the preliminary contribution in large scale and small scale projects.

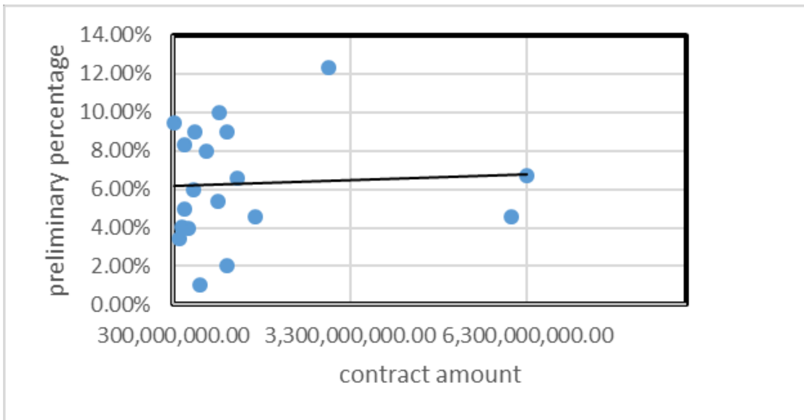

Figure 3: Preliminary Percentage of more than 300 million Projects

Mean and standard deviation also calculated to identify the average preliminary percentage in large scale projects. The mean value was 6.19% and standard deviation was 2.82%.

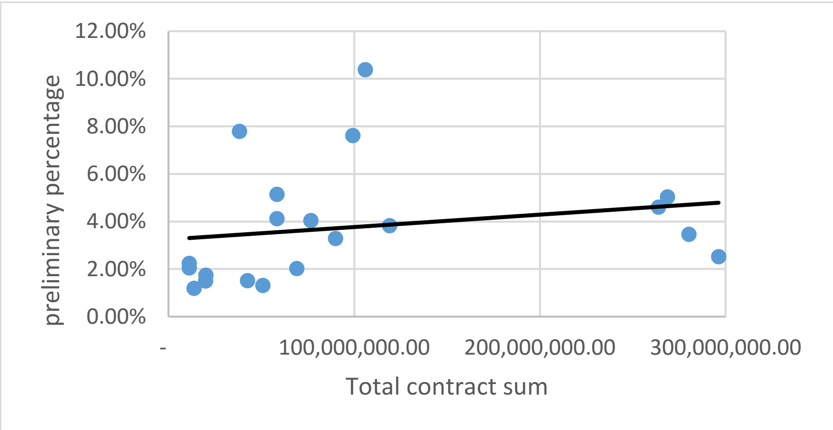

Figure 4: Preliminary Percentage of lesser than 300 million Projects

Above graph shows the relationship between preliminary percentage with the total contract sum. The mean value for the projects of contract sum not exceeding 300 million is 3.77% and the standard deviation is 2.41%. Compared to the above two categories, (see Figures 3 and 4) there is a positive relationship in both categories. That indicates the percentage of preliminaries increase with the increase of total contract sum. According to the calculations average preliminary percentage for building projects was 4.98% with a deviation of 2.89%.

4.4. IMPACT OF USING MINIMUM ITEMISED PRELIMINARY BILL

It was recognised that most of the times consultants advice to use a minimum itemised preliminary bill. Therefore, it was examined that the procedure of paying for the preliminary bill in a situation of time extension and how it is affected by not providing a detail preliminary bill. According to the clause number 44 of the CIDA conditions of contract (SBD 02), clause 8.4 of FIDIC conditions of contract 1999 which are mostly used conditions of contract in Sri Lankan construction industry, contractors have an entitlement to obtain additional cost incurred at an event of the time extension of the contract. It is important to have a detailed preliminary bill for the purpose of avoiding unnecessary disputes and claims arising from the construction for both parties. If there is a detail preliminary bill, the contractor is paid according to the relevant preliminary item to the relevant extended time in a situation of time extension where the contractor is entitled. It would be easy if there is a detailed preliminary bill for evaluation of the payment. If there is no any detailed preliminary bill, the contractor would include those cost in overheads. It is difficult to evaluate for which items should be paid. It could not be accepted because all the items in the overhead would not be affected by the time extension. It would be unfair for the employer. Most of the respondents mentioned that in a detailed preliminary bill, the preliminary cost is divided into establishment, maintenances and demolition as well as time-related, fixed and time to time items. Most of the times due to time extension time-related items and maintenance would be paid. However, if there is no any detailed preliminary bill all the fixed cost time to time cost are paid in overheads.

If minimum itemised preliminary is incorporated in the construction industry, standard practice is deteriorated. As an example as explained by an expert, health and safety and safety measures are not included in most of the preliminary bills. As a result of that, the contractor might determine his own standards for safety. Therefore, probably people would proceed with no safety boots, safety helmets and safety harnesses. If that preliminary item has been included in the preliminary bill and describes properly the safety procedures to be followed and the equipment required, it will enhance the standard of the construction industry. It would enhance the level of the labour not only the quality but also the attitudes. If these items are provided, employees will feel safe and the quality of the work would also be increased. If the labours were not provided with those safety measures it is very primitive and construction standards would not be enhanced and level of the construction would be same without developing. It is badly affected to the construction industry. Without having a detailed preliminary bill, it will cause lots of disputes in the future. Further, it will cause a delay in the project. If the employer needs the project urgently but due to the disputes, employer cannot take over the building at the right time. It would be a loss for the employer. Furthermore, at the tender evaluation stage, it would be difficult to evaluate. It directly affects to the construction industry when a detailed preliminary bill is not provided. As an example workers' facilities such as toilet facilities and sanitary facilities which was another preliminary item that is not mostly included in preliminary bill. However, according to the conditions of contract and law of the country, these facilities must provide. Therefore, contractors include low rate in their main trade item and not provide those facilities up to the desired level. Because of that labours will feel uncomfortable and they would move to other industries with better work environments such as hotels, factories and the like.

5. CONCLUSIONS AND RECOMMENDATIONS

Literature revealed that preliminary percentage compared to total contract sum is minimum 3% and not exceeding 10% for building work in construction industry. Further it was proved that preliminary percentage of building projects are about 4.98%. Furthermore, it was revealed that percentage for small scale projects is 3.77% and for the large scale projects it has increased to 6.19%. According to the work study preliminary items such as providing hoisting equipment and other plant, protection of public and private service at the site, providing an adequately trained person to attend to first aid medical duties including provision of a first-aid box, excavation for trial pits/ trial trenches and contractor's transport facilities at site were identified as least included preliminary items compared to CIDA standard bill. According to the analysis mainly clients' attitude towards the preliminary bill and the unprofessional conduct by the contractors were identified as main reasons for not including detailed preliminary bill. According to the expert opinions, deterioration of standard and quality of construction industry, impact to the employer, lack of investments towards the construction industry, subsidence of involvement in labours to the construction industry can be regarded as impacts that would be raised because of using minimum itemised preliminary bill. As per most of the experts that interviewed, it could be concluded that current CIDA standard bill for preparing preliminary bill was not followed by most of the construction industry people as the preliminary items included in the standard bill were not sufficient for all the building projects. Since it was found that size of the project was a critical factor when preparing the preliminary bill. Apart from that, some other factors should be considered when preparing the preliminary bill. As the most responsible regulatory body of developing and promoting Sri Lankan construction industry, CIDA has to consider about introducing comprehensive guidelines for each category of construction projects such as small-scale building projects and large-scale building projects. Even though the client asks to not to include the preliminary bill, the client need to be explained and advised on the consequences of not including relevant preliminary items by the consultant Quantity Surveyors. It would be helpful to minimise disputes among both parties.

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INTEGRATING INTERNET OF THINGS (IOT) AND FACILITIES MANAGER IN SMART BUILDINGS: A CONCEPTUAL FRAMEWORK

C.S. Suriyarachchi*, K.G.A.S. Waidyasekara and Nandun Madhusanka

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

A Facilities Manager (FM) plays a key role in managing all non-core services of a building by integrating people, processes, places, technology, and etc. Considering the effective integration of aforementioned sectors, a facilities manager needs to deal with the evolving information and communication technology. Presently, the most emerging trend is the "Internet of Things" (IoT) which is developing rapidly throughout the world. Subsequently, IoT concept is apparent in the field of facilities management mainly in the sector of building automation with intelligent controls. This intelligent automation results in creating SMART buildings which has become a global trend in the building sector. In such a situation, Sri Lankan building traditions should also be updated with the emerging IoT based technological trends to gain competitive advantages. Even though this is a timely requirement, user acceptance of new technologies and other external factors directly affects new IoT trends in Sri Lankan building culture. Due to the lack of data available in practice, this research was adopted using qualitative approach to identify the existing limitations and challenges of the integration of IoT and FM in smart buildings. This paper presents a conceptual framework which was developed by critically reviewing the secondary data. The proposed framework represents the relationship between FM and IoT in SMART buildings.

Keywords:*Facilities Manager; Internet of Things; Intelligent Buildings; Smart Buildings.*

1. INTRODUCTION

Beyond the traditional pattern of building operations, currently, massive numbers of technology evolutions are blooming to satisfy the requirements of building owners and the occupants sustainably. Almost all buildings are heading towards the automated structure. The International Facilities Management Association (IFMA, 2017) defines Facilities Manager (FM) as "a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, processes, and technology". Research findings of Ding *et al.* (2009) identified that from the operational stage onwards, the facilities management functions start and continue as key contributors in a building. Zawawi (2010) discovered that the current functions of the FM are covered a wide range and clearly mentioned that "facilities management is an umbrella term." Handling a broad area as the term of umbrella under facilities management, the 24/7 operation is highly considered by connecting with building through smart devices or wire connected device (Coleman, 2006). Physical operations will not disconnect from the virtual world anymore with the development of wireless technology as the numbers of objects being connected with each device and the era of communicating among the devices have arrived by introducing the Internet of Things (IoT) concept (Mattern & Floerkemeie, 2010).

As per the definition of IFMA (2017), integration of FM with many functions and changeable technologies should make a FM capable of managing the building by following the current trends and technological innovations. Otherwise, the profession will certainly become obsolete. According to Tan and Wang (2010), the future will change as machine-to-machine communication that will be as same as people talking to each other. The concept of the automated building requires many intelligent devices, and to perform the concept of intelligent building, there is a major requirement of a vast number of smart devices including materials and sensors (Runde & Fay, 2011; Wong *et al.,* 2008; Gilder & Croome, 2010). Integration of IoT devices within

*Corresponding Author: E-mail – sschamodi@gmail.com

the platform of the smart building will be controlled by focusing on enhancing the level of occupancy involvement to control the building as per their requirement (Agarwal *et al.,* 2010; Powell, 2010; Kiliccote et *al.,* 2011). Gartner (2013) and ABI Research (2013) suggested that the combination of IoT will develop through all the fields by 2020. Schlicket *et al.* (2013) mentioned that the development of the IoT concept with the combination of the connected devices would change lifestyles and enhance the performance of the culture of the world`s trend.

Internet of Things World (IoTworld, 2010) identified that IoT sensor market expects a faster rate of growth in the Asia Pacific region because most of the Asian population is integrating with consumer-related electronic devices. Therefore, the capability of accepting change is critical than regretting past failures and deficiencies. Research findings of Perera *et al*. (2016) pointed out that previous studies had lesser prioritised the urgent importance of FM in countries such as Sri Lanka. According to Ballesty (2007), the image of FM is challengeable. According to Yi *et al.* (2006), user acceptance is more important and challengeable when making changes, especially to technologically-related affairs that directly affect human behaviour. According to Tarandi (2012), many issues are involved in integrating IT concepts and software packages with building-related functions. While the innovation of technology is vast, Sri Lanka is not in a place to accept such changes immediately. As a result, the built environment has a wide gap between the building aspect and the technological aspect. East *et al.* (2012) mentioned that while the building has basic facilities such as functional enablers and numerous building systems, building owners are not allocating the adequate budget for expenditure due to financial issues and the lack of awareness of new systems. Therefore, considering the above facts concerning the developing countries where FM has already been integrated with SMART buildings, Sri Lanka has a requirement to investigate the involvement of FM and IoT in SMART buildings. Thus, this paper presents a conceptual framework which presents the FM involvement and integrating IoT in SMART buildings, as per the findings of the literature survey.

2. INNOVATIVE VISIONS OF FM AS A SERVICE PROVIDER

The concept of innovation is mostly considered under the production process, but some authors have conducted research on service innovation and linked it with the profession of FM (Cardellino & Finch, 2006). Goyal and Pitt (2007) mentioned that the innovation of FM will not happen automatically, but will occur by combining all the skills and capabilities of an organization while trying to achieve goals which are beyond the boundaries of the organization. Perera *et al.* (2016) argued that the FM profession will emerge from "boiler room" to "board room" in the future. Moreover, the same research emphasises that the Sri Lankan building sector is growing rapidly and the importance of FM is also growing on a tangent. These statements are a further testament to the future FM.

2.1. EVOLUTION OF FM IN SRI LANKAN CONTEXT

Nadeeshani (2006) has pointed out that Sri Lanka is developing with the increment of the number of high-rise and large-scale buildings. Moreover, the requirement of supporting services is increasing to satisfy the core requirement of the buildings. Mythiley (2010) stated that the role of FM is playing with several different identities of designation in the Sri Lankan context, while Cotts (1999) points out that the practice of the Sri Lankan FM depends on the cost and quality factors which fulfil the requirements than legal, environment, and social factors.

2.2. FUNCTIONS AND SCOPE OF THE FM

Barret and Baldry (2003) addressed the FM as an integrated approach to operating, adopting, maintaining, and enhancing the performance of the building, as same as the infrastructure facilities. The FM profession can be described as a multi-skilled profession that provides support to the core activities of a building by optimising the built environment performance (Ahamed *et al.,* 2013). According to Atkin and Brooks (2005) and Ancarani and Capaldo (2005), in addition to the operational functions of the building, FM has to perform with real-estate, finance, management contract and procurement, and health and safety functions. Figure 1 depicts the stages of the FM plans with respect to the functional goal achievements.

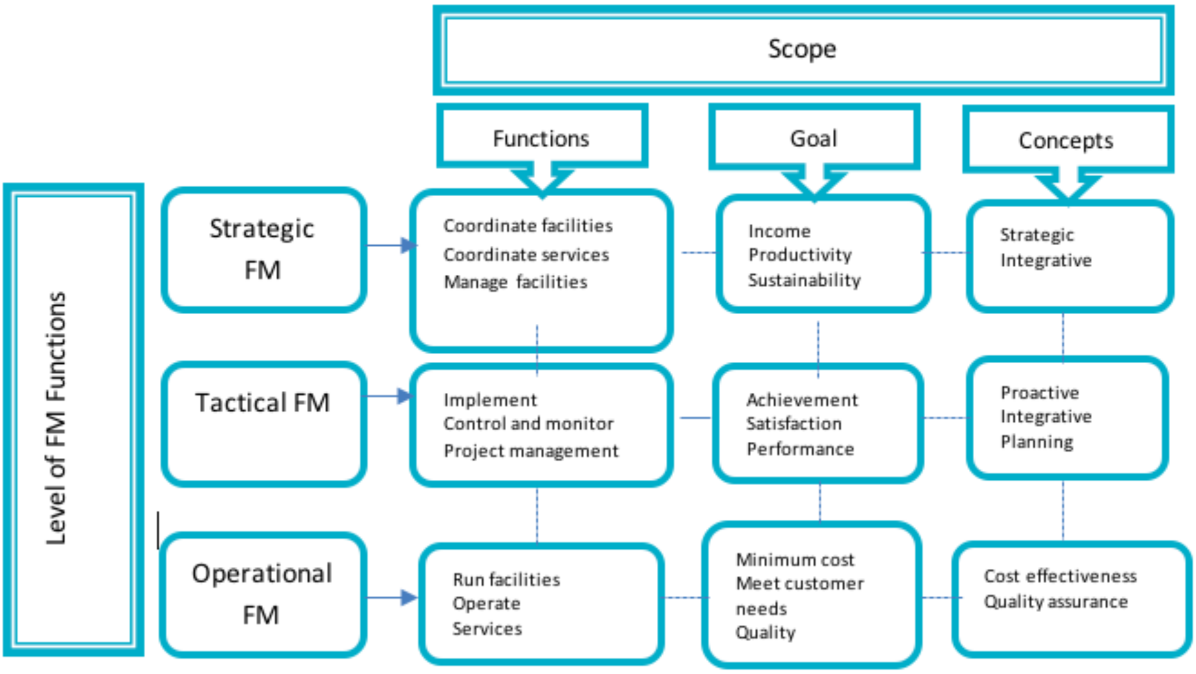

Figure 1: FM Functions and Scope

(Source: Adapted from Patanapiradej, 2012)

2.3. *TECHNOLOGICAL TRENDS FOR FACILITIES MANAGEMENT (FM)*

According to the survey results of the ISS World Service (2016), over 50% of the experts interviewed are expecting the facility management profession to grow more than the current situation by 2025.On the other hand, Evans (2011) mentioned that in 2020, the available population would be 7.6 billion, the connected devices will be 50 billion, and per person will use 6.58. This means that the internet connected devices will be increased beyond the population. Figure 2 illustrates the technological impact to the FM in future, based on the survey of CoreNet Global (2016). Accordingly, Mobile computing and IoT display high impact on future FM, and it is above 20%. This bear evidences of the importance of integrating technology for the survival of the future FM profession.

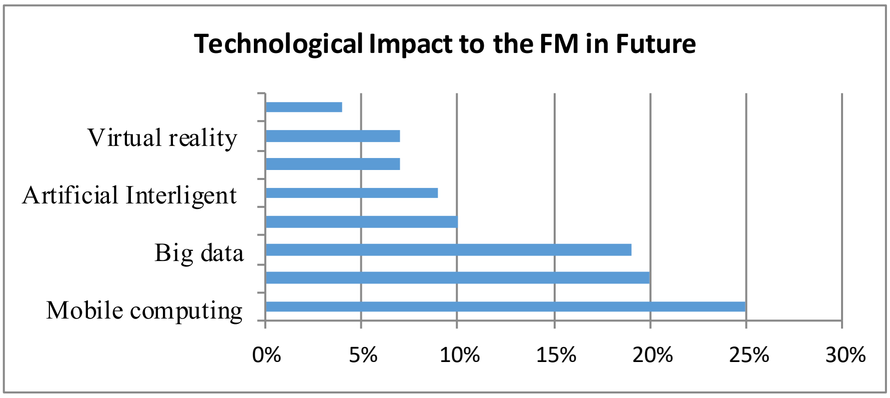

Figure 2: Technological Impact (Source: CoreNet Global Survey, 2016)

3. BUILDING INTERNET OF THINGS (BIOTS) CONCEPT

Information Society and Media Directorate General of the European Commission (DG INFSO) and the European Technology Platform on Smart Systems Integration (EPoSS) (2008) argued on the absence of a specific definition for IoT. They have suggested, "Things have identified and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts," and "Interconnected objects having an active role in what might be called the Future Internet." According to Gassée (2014), the industrial sector faces a critical issue relating to handing a number of remote controllers, which an author stated as "basket of remote". International Telecommunication Union (ITU, 2017) and Qiang et al. (2010) identified the difficulty of interconnecting all the subsystems into a single platform is a major issue of the new technologies with new upgraded building equipment, and the IoT network system emerged as a solution, connecting by various devices. Young (2014) stated that at the Realcomm advisory conference, the name IoT was amended to BIoT, indicating the Building Internet of Things (BIoT) to be used for all building components.

Miorandi et al. (2012) explained that the concept of the IoT is based on three pillars: (i) Identifiable, (ii) communicate, and (iii) Interact with the smart objects of the building networks. The Social devices, People as a Service (PeaaS), are specific linking models that can inter-connect people with objects (Atzori, Iera, & Morabito, 2014). Vermesan and Friess (2013) identified the technologies which are currently interconnected to perform BIoT aspects to be RFID, M2M, Internet of Services, Discovery System, Embedded System, Nano-electronics, Wireless Sensor Network, Cloud Computing, Cooperating System, Cooperating Objects, Energy efficient EVs, Systems of System, Software Agent, Robotics, Autonomic Systems, and Cyber-Physical Systems, which help to connect devices relating to the BIoT connected devices. RFID is the leading enabler of the concept IoT (Joung, 2007), and RFID can provide various functions such as identification and tracking real-time data with the location and the current status.

3.1. IoT Applications Related to FM Field

Casini (2014) stated that IoT could be used with all electrical devices, and also with building envelop to reduce energy consumption, react with climate conditions, and enhance consumer safety. Mil *et al.* (2008) researched on how to connect multiple requirements under integrating networks and sensors in a building. Ma *et al*. (2015) developed a theoretical framework by integrating IoT concept for building energy management system.

Considering the number of suppliers engaged with the IoT applications, the applicability is divided into a variety of sectors. According to O`Connor (2016), companies that are to have relationships with pilot projects are AT&T and Comcast. With respect to the above author, the project engages with the manufacturing of utility metering, environmental monitoring, asset tracking, lighting technology, networking for connected vehicle applications, vending machine applications and connected consumer devices, and product manufacturers.

3.2. FM Challenges

FM has to work with the main four functional areas of space management, technical management, administrative management, and all other building services (Lepkova & Vilutiene, 2008; Zavadskas *et al.,* 2002). These authors have further explained that working with the separate functions will require additional time and therefore, the FM should be entirely capable of integrating facilities to achieve a standard level of performance quality and time management with respect to cost minimisation (Sinopoli, 2010).

According to a case study conducted in Malaysia by Mustapa *et al.* (2008), the implementation of FM to an organisation confronts following challenges:

- Lack of understanding about the FM prevents the organisation's participation in the implementation of comprehensive FM strategies.
- Problem recovery after an occurrence generates issues of proper response due to the lack of technical knowledge and experience regarding FM.
- Lack of guidelines under FM to measure the desired level of the performance achievements.
- Owners of ageing buildings are not moving towards proper maintenance techniques under the guidance of FM because of the cost consideration and poor understating about current techniques.

3.3. Challenges of IoT

One major challenge facing IoT is the rapid increment of devices compared to the previous decades, which will cause the capacity of the data management, ubiquity, and scalability to fail to interact between the real and the virtual world (Kurzweil, 2006; Presser *et al.,* 2008). Moreover, IoT will merge into the population rapidly. In such case, various IoT devices will be required to be catered to the service and the cost of maintenance with the deployed time period of enablers will be an issue regarding the technology (Chen, 2012). Alberti and Singh (2013) found that the management of the IoT system will be an issue in three significant areas:

- With the number of devices being implemented, the traditional management model has to be the majority of the cost under the implementation.
- Almost all the devices are being dealt with by non-technical people.
- The IoT system needs advanced technology rather than the current traditional management network systems.

According to Beckmann *et al*. (2004), the lifetime of the battery is an issue since sensors are operated by batteries. While operating a process, the sensors cannot halt its function to change the battery or perform any maintenance activity. There should be battery-less low power sensors or any other solution to maintain operational continuity in the building processes. According to Shah *et al.* (2009),a widening gap between the population growth and IoT devices generates many security and privacy issues. Furthermore, most IoT base stations are designed to facilitate a specific number of connected devices and users. Although the system's capability is unlimited, the quality of the performance can suffer, and users may not receive uninterrupted services. This will generate major issues in reliability, security, and privacy than the other problems (Yan *et al.,* 2014). Moreover, numerous attacks and vulnerabilities can arise due to compromising with data privacy, as all data are gathered and analysed on the same IoT platform (Botta *et al.,* 2016).

Big data handling is another issue of the BIoT system that creates three challenges due to the vast amounts of data handled. They are numbers, variances, and speed of the data process. According to Wu and Tseng (2007), the resources available for processing, storage, and transmission are extremely limited with respect to the cost of the sensor coupled with simple circuitry. The other identified issue is the unavailability of global IDs or unique IDsfor the sensors (Kahn *et al*., 1999).

3.4. INTEGRATION OF IOT AND FM WITH SMART BUILDING CONCEPT

SMART building is "a subset of SMART environments" and that environment is "able to acquire and apply knowledge about the environment and its inhabitants to improve their experience in that environment". The SMART building is to be "allowed information and data about the building's operation to be used by multiple individuals occupying and managing the building" (Sinopoli, 2010). Zafari *et al.* (2016) stated that IoT and SMART building concepts are interconnected and interrelated, and SMART building relies on IoT devices. The major role played by wireless sensor networks (WSN) under the concept of SMART building is to interconnect devices that have a co-relationship with the IoT sensors (He *et al.,* 2013). Vinha *et al.* (2013) found that despite the use of BMS in high-rise buildings, there are limitations to its implementation in large-scale buildings. As a solution, BIoT is subject to be connected to objects using smartphones or smart devices to integrate IoT at the facility. Jansen (2012) states that smartphones act as an IoT service provider, while Mäkitalo (2014) reported IoT and other connected devices have its own communication protocols that will offer integration to the communication platform. Vermesan and Friess (2013) indicated that IoT sensors, which are enabled to communicate through cloud-based analytics software, are one of the main data collecting points for a facilities manager, which is crucial in managing building services when taking proactive actions.

New innovations related to IoT are connected to the FM requirements (Guinard *et al.,* 2011). Considering the service level of the integration, the relevant architect or the FM should know the functionality of the services and the applicability of relevant object to the related service (Chen *et al.,* 2010). As specified by Barnaghi *et al.* (2012) on the target of European Research Cluster (IERC) on the Internet of Things, "the major objectives for IoT are the creation of smart environments/spaces and self-aware things (for example, smart transport, products, cities, buildings, rural areas, energy, health, and living) for climate, food, energy, mobility, digital society, and health applications." Khattak *et al.* (2010) indicated that the "SMART" term is connected with the Green concept, and simultaneously, enhancing IoT-related services by moving with the smart buildings.

3.5. CONCEPTUAL FRAMEWORK FOR INTEGRATING IOT AND FM IN SMART BUILDINGS

Based on the literature findings, the study identified three main vital aspects as; i) Layers of SMART convergence, ii) Steps of IoT process, and iii) Role of FM under IoT, as presented in Figure 3. The Physical world, informational world, and SMART building World were identified as the three layers of SMART building. As found from literature, the Physical world works as data collection or gathering pre-defined data and storing suitably. Storing process continues with the cloud-based system. Then, through the cloud, informational world activates by data analysing and filtering required data from the collection of mass collection data. Inthe smart world, the physical and informational world will integrate the process to activate the smart building options.

During the IoT process step, IoT enablers work as the primary root of the IoT process as data identification and react to the commands. The User gives commands through the smart building applications, and operation is performed by reversing the data flow process. Throughout this process, Wi-Fi plays a significant role and act as the operation back bone. The FM then interconnects the integration of BIoT with the smart building.

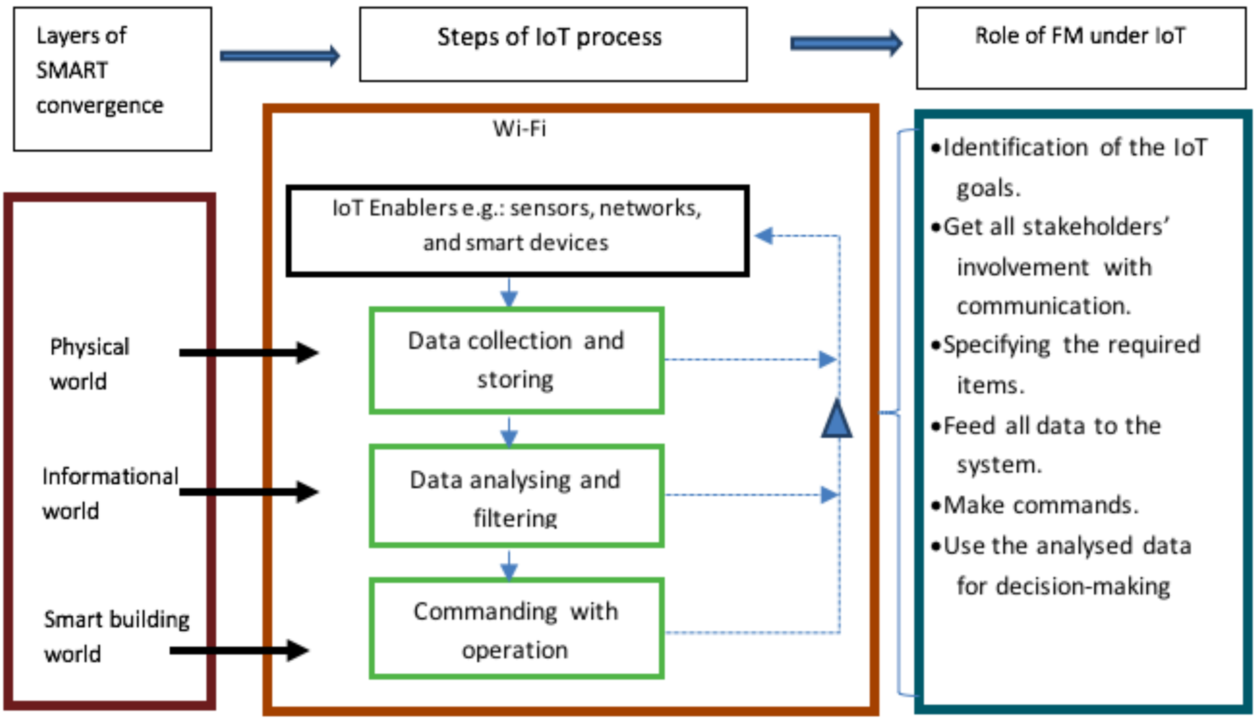

Figure 3: A Conceptual Framework for Integrating IoT and FM in Smart Buildings

The FM has many functions to perform from the initial implementation to the operation of the process. E.g., IoT enablers connect with the HVAC and the informational world make decisions based on the data acquired through the physical world. The Wi-Fi covers the total premise and ultimately operates as a self-controlled way to identify the maintenance issue of the HVAC by notifying relevant persons with real-time data without entering a human in the process. The primary intention of this framework is to perform all monitoring and control activities of FMs through IoT integration, rather than all documentation, assets movements, and space management to happen with the SMART IoT in a building. The ultimate target is to increase the profit by reducing the cost of operation and maintenance in the real-time tracking with more accruable strategies. Finally, the developed conceptual framework (refer to Figure 3) represents the summary of literature findings to integrate the IoT and SMART building concept with the involvement of FM based on available secondary data.

4. CONCLUSIONS

Literature bears evidence that technology has developed to provide support for human activities. IoT is the latest technology for the buildings, which enhance the performance of building culture. However, despite various innovated technologies, Sri Lanka is slow in accepting these changes. Therefore, this research has focused on investigating the involvement of FM and IoT concepts in SMART buildings. Accordingly, a conceptual framework was developed through the findings of literature. It represents the relationship between FM, IoT concepts, and SMART buildings. This framework should be refined with the actual context to identify possible pathways to integrate FM with IoT concept in Sri Lanka.

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INTEGRATING LEAN AND GREEN CONCEPTS: SRI LANKAN CONSTRUCTION INDUSTRY PERSPECTIVE

T.P.W.S.I. Pandithawatta*, Niza Zainudeen and C.S.R. Perera

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Construction industry developers and project teams usually struggle to associate the concept of Green on building projects since it is generally resulting in high initial investment cost. Although this cost of investment can be saved back through operational stage, the current building project delivery methods implemented by most project teams are often laden with non- value adding activities. Lean construction principles have been convinced to eliminate flow activities and improve construction process performance in highly complicated building construction projects. Hence, the aim of this research is to explore and develop a framework to integrate Lean and Green concepts to the Sri Lankan construction industry.

At the outset, the key features and principles of Lean and Green construction were identified to build the conceptual relationship between the two concepts. Subsequently, a qualitative research approach was adopted through the means of expert opinion survey with unstructured interviews involving ten number of local expert professionals who have experience and exposure to both of these concepts. The findings were analysed through content analysis.

The perception of the Sri Lankan stakeholders towards the application of integrated Lean-Green concepts is focused on a positive direction. The identified enablers to implement the integrated concept supersede the barriers by confirming the appropriateness of the application in the local construction industry. The Green concept was integrated into the activities that are implemented under each Lean construction principle. Finally, a framework was developed through the findings to guide the implementation of integrated Lean- Green application in Sri Lankan context.

Keywords: *Flow Activity Elimination; Green Construction Process; Integrated Lean-Green Application; Lean Construction Principles.*

1. INTRODUCTION

The construction industry contributes to the economic growth, both by its direct and indirect activities through the provision of buildings and infrastructures for the undisturbed functioning of businesses (Peng & Pheng, 2011). However, construction activities are also creating broader problems and issues affecting the environment, including global warming, climate change, ozone depletion, soil erosion, desertification, deforestation, eutrophication, acidification, loss of diversity, land pollution and consumption of valuable resources such as fossil fuels, minerals and gravels over their entire lifecycle (Ahn & Pearce, 2007).

With the emerging recognition of negative environmental impacts, the construction industry is pushed to take environmental considerations into the decision making processes (Yates, 2007). Hence, the industry is constantly being forced to minimise its large amount of energy consumption, raw material and water usage (Low et al., 2012).

Construction companies from various regions around the world are controlling the impact to the environment by integrating Green concept into their construction plans (Hwang & Tan, 2012). Many efforts have been undertaken such as process and technology innovation (Spence & Mulligan, 1995), adopting low carbon fuels

*Corresponding Author: E-mail – sonalitpw@gmail.com

(Hendriks et al., 1998), identifying alternative low carbon raw materials (Gartner, 2004) and CO_2 capture and sequestration (Herzog, 2001) to achieve long term sustainable development by reducing carbon emission.

Other than for the above discussed issues, construction industry is well known for low productivity, poor safety, inferior working conditions and insufficient quality. A number of solutions such as industrialization, computer integration and automation have been offered to control these problems (Koskela, 1994). Furthermore, the Lean construction can be utilized to minimise the overall cost while maintaining the quality standards and reducing cycle time (Womack & Jones, 1996).

Theoretically, Green construction focuses on reductions in building energy use, water consumption, materials employed and pollution (Abidin & Jaapar, 2008). On the other hand, Lean construction emphasizes on eliminating unnecessary activities while reducing waste in the processes used to design and construct buildings (Koskela, 1994). Although these two concepts have two different goals, it is clear that both the concepts exhibit significant synergies on minimizing resources use (Jamil & Fathi, 2016). The journey towards greener operations and products has pushed companies to search alternatives to balance efficiency gains and environmental friendliness in their operations and products. The exploration of the sequential or parallel deployment of Lean and Green concepts is the result of this balancing action. Further, the Lean concept's alignment with the Green paradigm, and its methods and tools seem natural as it aims on eliminating waste (Garza-Reyes, 2015).

As a result, Lean and Green relationship has the potential to bring in benefits in terms of positive environmental and economic outcomes to Sri Lankan construction industry. Yet, no investigations have been done to investigate the effectiveness of integrating those two concepts in the Sri Lankan construction industry. Thus, an attempt of integrating Lean concepts with the Green concepts seems an appropriate and effective effort which needs an in-depth investigation. Therefore, it is a timely need to carry out a comprehensive study on integrating Lean and Green concepts from the Sri Lankan construction industry perspective. Hence, the research was undertaken to explore and develop a framework to integrate Lean and Green concepts to Sri Lankan construction industry.

2. LITERATURE REVIEW

2.1. CONCEPT OF LEAN

Lean is a well-known philosophy originated from the Toyota production system, that targeted on eliminating all the expenditures on resources which do not create a value to the end customer (Čiarnienė & Vienažindienė, 2015; Ohno, 1988). The process of eliminating non-value-added activities, reduces the costs and cycle time which increases the customer responsiveness as well as the effectiveness and the competitiveness of the organization (Alukal, 2003).

The Lean production system categorize all the activities of the production system in to two main categories, based on the value that they are creating on the end product or process. Thereby the value adding activities referred to as Conversion activities while non-value adding activities which consumed resources and time, referred to as Flow activities (Koskela, 1992). To create an environment where Flow and Conversion activities were treated separately, Lean production system improved the Conversion activities and eliminated the Flow activities (Peng & Pheng, 2011).

According to Koskela (1992), eleven basic principles to Lean construction to be implemented to the total flow process and its sub process in the construction industry are; (1) reduce the share of non- value adding activities, (2) increase output value through systematic consideration of customer requirements, (3) reduce variability, (4) reduce the cycle time, (5) simplify by minimizing the number of steps, parts and linkages, (6) increase output flexibility, (7) increase process transparency, (8) focus control on the complete process, (9) build continuous improvement into the process, (10) balance flow improvement with conversion improvement and (11) benchmark. Moreover, these principles are under the core principle of eliminating non- value adding flow activities and increasing value adding conversion activities. Thus, the adoption of the core principle supports the adoption of sub principle without any extra effort.

2.2. CONCEPT OF GREEN

Industrialisation and globalisation have greatly influenced the global eco system when the agriculture based society transformed into an industrial society. Further, the improvements in the global economy have increased the use of energy level while exploiting the natural resources. Subsequently, such actions have led to an increase in the atmospheric concentration of carbon compounds and also phosphate and nitrogen concentration in soil and water at an aggressive rate. Moreover, this has caused in loss of biodiversity, soil erosion and other environmental degradation (Amiolemen et al., 2012).

Green is now a major concept in development thinking at all levels. Over the last few decades there has been an increasing understanding of the world and its occupants as a single system and of the requirement to integrate two key universal aims in the development of human activities: to eliminate the depletion of the resources and biological systems of the planet for the future generation's needs while at the same time to expand human development, specially in the underprivileged countries and to remove the inequities prevail in the world today (Spence & Mulligan, 1995).

The construction industry and building sector have a considerable contribution towards numerous negative environmental impacts (Illankoon et al., 2017). According to Pink (as cited by Illankoon et al., 2017), construction industry considered as one of the major industries which emits greenhouse gases significantly while contributes about 26% of waste. Further, Pulselli et al. (2007) revealed that construction industry exploits almost 40% of the world's consumption of materials. In addition, with the growing recognition of global climate change, there is a huge pressure on the construction industry to take environmental parameters into the daily decision making processes (Peng & Pheng, 2011).

Green construction could be identified as an integrated framework of design, constructions, operations, maintenance and demolition processes that consider the environmental, social, and economic effects of the construction projects (Li et al., 2015). Green construction recognizes the interdependence of built and natural environment while associating energy efficient products and renewable energy such as solar, biomass, wind, hydropower, biodiesel and geothermal into the projects (Ali et al., 2016). According to the U.S. Environment Protection Agency (EPA) (as cited by Illankoon et al., 2017), green buildings reduce the overall effects of the built environment on natural environment and human health by efficient use of water, energy and other resources, protecting occupant health and improving employee productivity while eliminating pollution, waste and environmental deterioration.

2.3. LEAN AND GREEN INTEGRATION INTO THE CONSTRUCTION INDUSTRY

The journey towards greener operations and products has pushed companies to search alternatives to balance efficiency gains and environmental friendliness in their operations and products. The exploration of the sequential or parallel deployment of Lean and Green concepts is the result of this balancing action (Garza-Reyes, 2015). Bergmiller and McCright (2009) suggested that the parallel implementation of two concepts create more chances to be successful by minimising cost and waste. Lean management creates positive effects on environmental management, which itself has a favourable impact on operational performance (Jabbour et al., 2013). Meanwhile, Dües et al. (2013) identified Lean as a catalyst for the implementation process of Green in manufacturing companies and that Green supports in return to manage best practices in Lean.

Lean construction and Green construction practices are generally considered as two different independent strategies where Lean process aims on increasing economic standards while Green aims on improving environmental objectives. Through number of researches and industry practices it was proven recently, that the two practices are interdependent and shares the exact basics of waste reduction (Khalfan et al., 2001). Moreover, Koranda et al. (2012) stated that the concepts of Green construction and Lean construction are similar because both the concepts aim to reduce waste during construction. Therefore, Meng (2012) and Smith (2003) suggested that the Green construction components can be integrated into the concept of Lean construction to improve and preserve environment, natural resources and economic growth.

3. RESEARCH METHODOLOGY

The research was aimed at exploring and developing a framework to integrate Lean and Green concepts to Sri Lankan construction industry. At the outset, a literature survey was carried out to identify the key features and principles of Lean and Green construction to recognise the conceptual relationships between the two concepts. To fulfil the aim of this research, it was required to investigate the perception of the construction stakeholders and expert's opinions, experiences and knowledge. Despite the fact that the quantitative studies deliver more reliable and unbiased results, it requires large number of respondents to carry out the study. Since the Lean and Green concepts are new to the Sri Lankan construction industry, only a few number of experts were identified. Therefore, the research ultimately dealt with qualitative data as the study can be carried out with a lesser number of respondents. The purposive sampling method was used through to identify professionals with both Lean and Green awareness and experience. As a result of that, ten experienced industry professionals with more than ten years of experience who have engaged in large scale construction projects in Sri Lanka were selected as the interviewees to carry out the expert opinion survey. To get a wide range of responses, interviewees were selected from both the consultant and contracting fields with some managerial responsibilities. All of them were having experience with projects that have implemented Green concept. The experience and exposure of the interviewees with related to the Lean and Green concepts were given in the Table 1.

Table 1: Composition of Respondents

No	Designation	Industry experience	Level of awareness		Level of experience in practice	
			Lean	**Green**	**Lean**	**Green**
(1)	Site engineer	Above 15 years	Moderate	High	Moderate	High
(2)	Planning engineer	Above 15 years	High	High	High	High
(3)	Managing engineer	Above 10 years	High	High	High	High
(4)	Architect	Above 10 years	Moderate	High	Moderate	High
(5)	Project Manager	Above 15 years	High	High	Moderate	High
(6)	Quantity Surveyor	Above 10 years	Moderate	High	Moderate	High
(7)	Quantity Surveyor	Above 25 years	Moderate	High	Moderate	High
(8)	Project manager	Above 15 years	High	High	Moderate	High
(9)	Project manager	Above 20 years	High	High	High	High
(10)	Architect	Above 15 years	Moderate	High	Moderate	High

Unstructured interviews were carried out with open-ended questions. Code-based content analysis was selected as the data analysis technique as it allows convenience by minimizing data to be analysed which gathered through the interviews. For coding and simplifying the collected data, computer software N-Vivo 11 was used in this study with graphical presentation of interpreting relationships, combined with descriptive analysis where appropriate.

4. RESEARCH FINDINGS AND DATA ANALYSIS

4.1. SRI LANKAN STAKEHOLDERS' PERCEPTION TOWARDS THE LEAN- GREEN APPLICATION

Investigating the perception of the Sri Lankan construction stakeholders towards the Lean- Green application is critical before its introduction to the industry. Therefore, the contribution of Lean concept to the Green construction, the applicability of Lean- Green approach and enablers and barriers for its implementation were thoroughly investigated from the view point of Sri Lankan construction stakeholders.

4.1.1. CURRENT STATUS OF LEAN AND GREEN APPLCATION IN SRI LANKAN CONSTRUCTION INDUSTRY

Green concept; Even though it was proved that the concept of Green would bring out number of advantages to the construction industry, without practicing this concept none of these returns can be gained. All the respondents without any contradictory opinions exposed that the current performance of Green building delivery process is in an unsatisfactory level. Out of the ten responderesponts nine stated 'material and technology deficiencies' as an major issue that need to be addressed immediately. It was also revealed that the number of Green professionals that can be assigned in to Green projects is not sufficient in local context. Therefore, the respondents suggested 'improving sustainable education and training of the construction professionals' as an important solution which will favourably change the Green building delivery process.

However, few respondents expounded some managerial issues relating to the 'low effectiveness connected with the Green building delivery process'. According to those respondents, the Green construction process needs a set of principles which is compatible with Green aspects and increases the efficiency level of the delivery process. The findings emphasised the need of the Sri Lankan construction industry to seek out an effective set of principles that can be conveniently used in a Green construction project. This view has supported the aim of this research and proved the importance of using performance improving principles compatible with the Green aspects. The respondents were also emphasised 'the deficiencies in the green building certificate process' and 'contractor's lack of knowledge on their contribution to the Green building delivery' as concerns in implementing Green concept in construction industry.

Lean concept; The adoption of integrated Lean- Green approach is highly influenced by the present Lean application level in the industry. A high level of practice would be helpful to introduce the new approach since the industry know the benefits associated with it. However in terms of local context, the respondents highlighted that the application level of the Lean construction principles are in a moderate level but most of the time it is applied unconsciously without a complete knowledge on the subject area. Therefore, this unconscious implementation would not bring all the benefits to the projects. Out of ten, nine respondents emphasised, 'the insufficient knowledge relating to the Lean concept' as the main reason for the lack of application of the concept in the Sri Lankan construction industry. Other reasons such as misconception, implementation issues, insufficient management support and resistance to change are occurred due to the inadequate knowledge were also pointed out by the respondents. Therefore, to improve the current Lean application level in Sri Lankan construction industry these issues need to be addressed immediately. Respondents also highlighted 'the hierarchical project organisation structures' as an issue to implement some of the Lean construction principles. Therefore, it was proposed to adopt self-directed work teams in construction project management to deliver maximum benefits of the Lean construction principles.

4.1.2. CONTRIBUTION OF LEAN CONCEPT TO THE GREEN CONSTRUCTION

With the performance deficiencies embodied in the Green building delivery process, the industry is in a status quo to find out a method to overcome this issue. Therefore, the opinions of industry experts on the contribution of Lean concept to the Green construction is important to a great extent with the aim of evaluating perception on integrated application. Majority (8 out of 10) of the respondents identified Lean as a means of reducing wastage through the elimination of non-value adding activities which is beneficial in maintaining the environmental standards. Further, Lean was recognised as a concept that helps to maintain the site in a clean and orderly manner which will indirectly contribute to eliminate accidents on site and thereby increases the social value of the project. Lean provides the platform to maintain the machines, tools and equipment in a way that improves its efficiency level. Such performance increments result in economical benefits to the project. Aforementioned economical, social and environmental benefits that were identified by the Sri Lankan construction experts proves that Lean implementation is capable to deliver important Green impacts to a project. Most of the respondents agreed that there will be an enormous contribution if Lean is exercised along with the Green concept. Yet, experts disclosed that the compatibility of each principle needs to be analysed before its application in a Green building project.

4.1.3. ENABLERS AND BARRIERS IN IMPLEMENTING LEAN- GREEN APPLICATION

All the respondents had unanimously agreed that there are enablers available in the construction industry which will support the implementation of Lean-Green application. They also highlighted the importance of strengthening these enablers in order to accelerate the process. Majority (8 out of 10) of the respondents identified 'the opportunities available to increase the knowledge level relating to Lean and Green' as an enabler. The contribution of the consultants towards the Lean-Green application was intensified by most of the respondents (7 out of 10). Research findings explicated that the influences of the consultant can play a major role to upgrade the quality of the project through introducing new concepts. The Government involvement was also identified as an enabler which can positively influence the implementation of integrated approach.

All the respondents highlighted that the retarders of the implementation process of integrated approach is an amalgamation the barriers of implementing individual concepts. However, it was also identified that the integration may lead to overcome the each other's barriers. For example, the high initial cost of the Green concept implementation can be economised with the integration of the Lean construction principles. Lack of professionals, high initial cost of Green construction and lack of knowledge about the integrated approach were recognised by the most of the respondents as the barriers to the integrated approach. However, the respondents further exposed that strengthening the available enablers that accelerate the implementation process will help to overcome those barriers by ensuring the successful execution of the Lean- Green approach.

4.2. INTEGRATED LEAN- GREEN APPROACH

4.2.1. THE DEVELOPMENT OF THE INTEGRATED LEAN AND GREEN FRAMEWORK

The findings related to the Lean principles revealed some relationships in between those principles. It was clearly observable that all the Lean construction principles have a contributory relationship with eliminating flow activities and improving conversion activities. Some of those relationships were having direct contribution while others were having indirect relationships. These indirect and direct relationships are illustrated in the Figure 1. Four principles were identified as indirectly influencing principles towards the elimination of flow activities. It was also observable that these principles directly influence the implementation of other principles, which directly contribute to the flow elimination. For example, benchmarking does not directly eliminate the flow activities and improve the conversion activities, but does direct influence to improve the construction process continuously which would be resulted in flow elimination. Therefore, benchmarking could be included or integrated under the principle of build continuous improvements.

Identification of social and environmental requirements along with the customer requirements was proposed by the respondents as a means of achieving variability reduction in the Green building delivery process. Therefore, 'requirements consideration' can be implemented under the principle of 'variability reduction'.

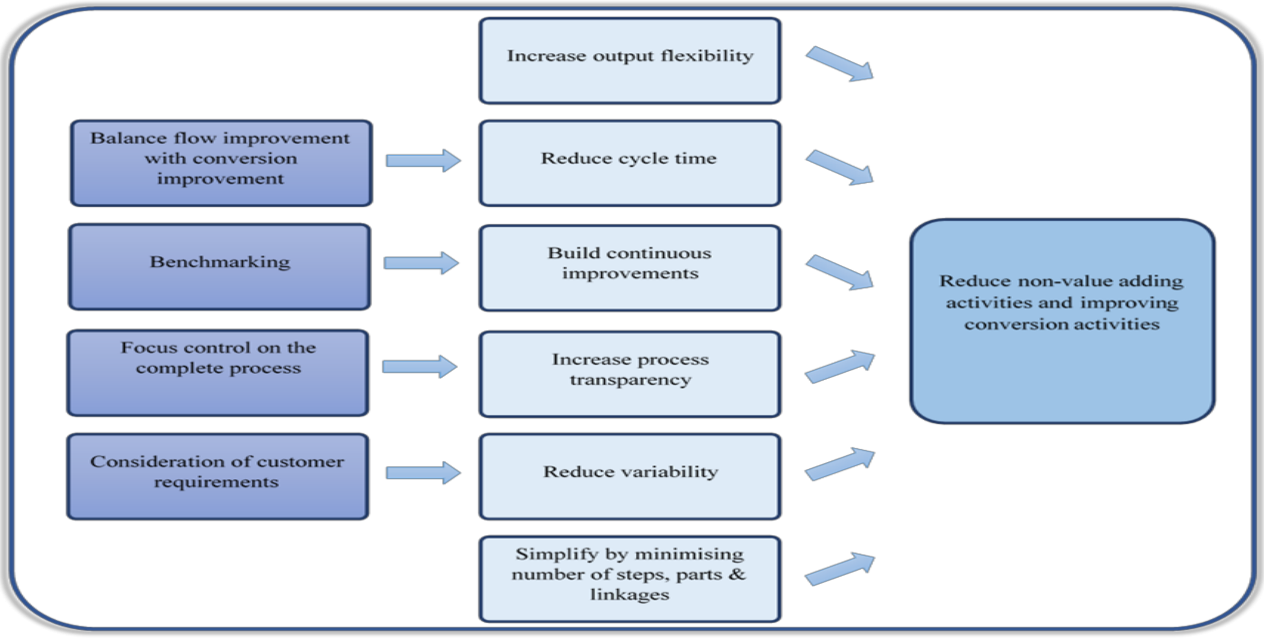

Figure 1: Relationships Among Green Integrated Lean Construction Principles

The respondents' opinions related to the cycle time reduction intensified the necessity of considering the environmental and social aspects. This has forced to keep a balance in between the flow elimination and conversion improvements to minimise the negative environmental and social impacts. Therefore, the principle of 'balancing flow improvement with conversion improvement' can be implement under the principle of 'cycle time reduction' in order to achieve Greener results.

According to the opinions of the respondents, the transparency of the construction process can be increased through the holistic controlling of the complete construction process. Using self-directed teams and flat organisation structures to execute the construction work increases the flow of information within the project and allow to reach only the information that are relevant. Therefore, the principle of 'holistic controlling' can be implemented under the principle of 'increasing process transparency'.

The research findings have set the path to identify the relationships between the Lean principles when the concept of Green is integrated. Among the interactions, the framework was built upon the relationship that the principles are having with flow activity reduction. Framework will mainly address the flow and conversion activities associated with the Green construction process. It provides a platform to eliminate flow activities and to improve conversion activities in a way that it facilitates the Green concept. Six main aspects of the Green construction process namely; process variability, cycle time, transparency, simplicity, flexibility and continues improvements are focussed to make the process more productive and economical. Giving prominence on those aspects would result in reduction of flow activities and improvement in conversion activities.

4.2.2. Integrated Lean and Green Framework

Lean construction and Green construction practices are ordinarily considered as two different independent approaches where Lean focuses on improving economic measures while Green aims on advancing environmental objectives. The implementation of Lean has indirect positive Green impacts but it can have negative impacts as well. If it is possible to set environmental and social issues as values to achieve at the beginning of Lean implementation, issues can be addressed and Green products will be delivered in an effective way. The integrated Lean- Green framework was developed based on this phenomenon where it will set the path to achieve a Green facility effectively by eliminating current pessimisms. The developed integrated Lean-Green framework based on the findings is illustrated in Figure 2. The given activities are prioritised based on the response rate of the relevant activities since it was assumed that the highly influential activities were the mostly suggested activities by the respondents. All the dotted activities that are shown in the framework do not have any negative impact on the Green concept. The activities that are shown in italic will have positive impact if those activities can be implemented along with the aforementioned activity. The barriers and enablers of the integrated Lean-Green application are demonstrated in the priority order to highlight the most influencing factors.

5. Conclusions

The ultimate aims of Green and Lean concepts are different since they are aiming on improving different aspects of construction projects. Yet based on the principles and key areas, the study exposed that a relationship can be established since both the concepts are focusing on improving the standard of the construction projects. The findings also revealed that the high initial cost of the Green concept implementation as the major concern addressed with the use of Lean concept. The eleven Lean construction principles identified act as the means of economising the cost of Green building construction process and increasing the performance level. Further, it was identified that the exclusive implementation of Lean concept may not be compatible with the Green standard of the project, since Lean does not take social and environmental aspects into the consideration. Therefore, the importance of implementing Lean concept integrated with the Green concept was recognised. Sri Lankan construction stakeholders have acknowledged the contribution of the Lean concept to the Green building delivery, which is the key governing factor to decide their perception in relation to the Lean- Green application. The implementation process is associated with numerous enablers and barriers where the barriers can be mitigated through strengthening the enablers. The integrated Lean- Green framework will allow to adopt a consistent construction process which would bring productivity to the project. The framework is based on six filtered Lean aspects of the construction process, namely process variability, cycle time, transparency, simplicity, flexibility and continues improvements. Moreover, the framework allows the Sri Lankan construction industry to improve its efficiency while adopting to Green considerations.

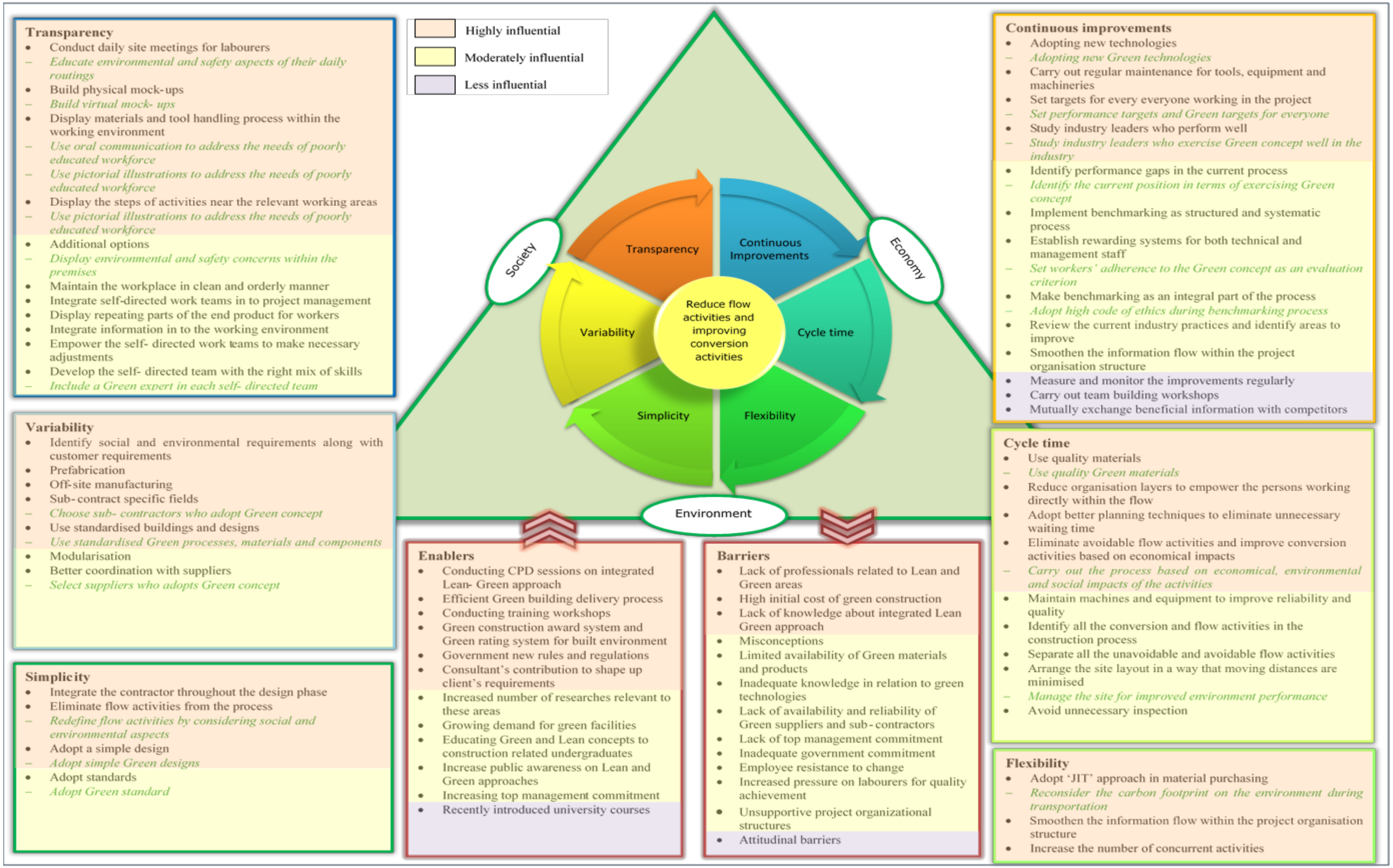

Figure 2: Integrated Lean- Green Framework

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INTEGRATION OF SUSTAINABILITY INTO FACILITIES MANAGEMENT PRACTICE IN HEALTHCARE SECTOR

Nazeer Fathima Sabrina*, Thanuja Ramachandra and Sachie Gunatilake

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Built environment is recognised as one of the least sustainable industries in the world. Health Care (HC) sector is recognised as the second energy intensive sector in the built environment and is identified as one of the most vulnerable sectors and a potential threat in harming the environment. As Facilities Management (FM) is recognised as a "key actor" in addressing sustainability practices in the built environment, it has become a major concern to deliver FM practice in a sustainable manner. However, integrating sustainability is challenging as sustainable FM practice is firm specific and need consideration of economic, environment and social pillars of sustainability. Thus, this paper investigates how sustainability practices can be integrated in to the FM services and practices in the HC sector.

A Delphi survey was conducted among 10 experts to identify the significant FM services and FM practices to integrate sustainability in the health care sector. The first round of Delphi survey revealed that building services (BS), quality management (Q) and space planning (SP) are the top three FM services for integrating sustainability with RII values of 0.94, 0.9 and 0.9 respectively. In addition, 28 FM practices were identified significant, amongst, educating the work force on related standards, procedures, Strategic Facility Planning (SFP) for HC and deploy quality control and assurance practices with proper standards was identified as three top most FM practices with receiving an RII of 0.96, 0.96 and 0.94 respectively. A conceptual framework was developed for effective integration of sustainability into FM practice comprising of 8 FM services, 28 FM practices and 78 sustainable practices. This will further to be taken to the subsequent rounds of the Delphi survey to refine the conceptual integration of FM services, practices and sustainable practices for effective integration of sustainable practice into the FM practice in the HC sector.

Keywords:*Facilities Management; Healthcare Sector; Sustainable Facilities Management.*

1. INTRODUCTION

Sustainability has become a major obligation in the built environment as it faces major challenges around the world due to its significant impact on the environment (Chotipanich & Lertariyanun, 2011). For example, buildings are estimated to use 45-50% of energy, 50% of water out of the total global resources and in the meantime responsible for polluting the air in cities by 23%, emitting greenhouse gases by 50% and landfill waste by 50% out of the total global pollution (Dixon, 2010). Among the built environment sector, HC sector is recognised as the second energy intensive sector and emits around 8% out of total 40% of CO_2 emission (Kras, 2011). In addition, HC sector in US alone generates over 3 million tons of solid waste per year consisting of hazardous solid, toxic, infectious and radioactive wastes (Davies & Lowe, 1999). In addition, clinical waste in HC sector is ranked among the top 4 sources in emitting and spreading harmful substances which lead to cause respiratory diseases and other illnesses to the community (Buffoli *et al.*, 2014). Moreover, unlike the other facilities such as; office buildings or educational or industrial facilities or hotels, HC sector is categorised under critical facility as it could bring many harm and damages in an operation failure (Torell, 2012). Further, "care for the healthy" is the core objective of the HC sector in which both delivery of medical care and delivery of non-core services to satisfy patients and visitors wellbeing needs equal importance (Wu, 2011). Even though HC is recognised for "caring for the healthy" it undermines the population by being a threat to their health and

*Corresponding Author: E-mail – sabrinanazeer@gmail.com

wellbeing by failing to meet the social responsibility. Thus, there is a general push to bring the HC sector to incorporate sustainable practices.

This creates a demand for Facilties Management (FM) to adopt sustainability in the HC sector as they are identified to be in an unique position to deliver real differences in retrofitting sustainability practices in buildings (Elmualim *et al*., 2012). This leads to many benefits such as; financial returns, reducing energy consumption and waste, while increasing productivity and standing in the community (Hodges, 2005). This shift in FM is described as "sustainable movement" for FM today where Sustainable Facilities Management (SFM) was acknowledge (Meng, 2014). However, lack of understanding about sustainability and unwillingness of integrating sustainability are preventing FM from practicing sustainability (Elmualim *et al*., 2009)**.** The general idea of SFM is to incorporate sustainability practices into the operations of FM practices (Baaki *et al*., 2016). In essence, Nielsen and Galamba (2010) assert that, SFM does not create totally new practices, but rather incorporating practices concerning the social, economic and environmental pillars of sustainability into the existing FM practice. In this context, SFM is defined as "delivery of sustainability within FM" (Shah, 2007). In another definition by IFMA (2016) stated SFM as "integrating the people, place and business of an organisation that optimises economic, environmental, and social benefits of sustainability". Hence, both the definitions state moreover the same meaning that SFM means integrating sustainability into the current FM practice. However, facility managers apparently suffer from a kind of blind spot on integrating sustainable practices into the current FM practice as there are no visible SFM practices streamlined to integrate sustainability into the current FM practice in HC sector (Baaki *et al*., 2016).

Furthermore, SFM practice is challenging as it tends to differ in number of ways in different facility types from offices to housing, retail locations, healthcare, hotels, universities, world heritage sites and others. These facilities, from technical building components to the usage and economic contexts it differs, thus, requiring to seek FM practice and sustainable practice on specific context (Price, 2004). For instance, FM services such as building services management, real estate management, risk management and quality management, etc. require different type of sustainability practices (Nutt, 2004). Nielsen *et al*. (2009) highlighted this on integrating SFM practices in the operations of housing estates in Denmark. The research identified green accounting, individual metering, energy management and energy labelling of buildings as some of the sustainable practices mostly emphasised in the housing sector. Shari and Soebarto (2014) highlighted eliminating sick building symptoms, accessibility to public transport, energy efficient facilities, water efficient facilities and 3Rs in waste management practices etc as most significant sustainable practices to be focussed by office buildings in Singapore. Furthermore, use high quality and long lasting material (linen), recycle waste water, install low-flow sinks, toilets, showers and design to preserve views were highlighted in hotels (Ahn & Pearce, 2012). This showcases that, different types of ownership demand different types of FM practice thus determining the success of SFM. This creates the necessity of streamlining the SFM practice to be compatible with the HC specific context.

This paper reports results of a study attempting to gain insights about FM practice and how sustainable practices can be integrated in the HC sector. In attempting to gather empirical evidence, the study adopted Delphi survey to collect data and information from the key persons concerning FM practices in HC sector. Its key findings provide not only empirical results of FM practice, but also conceptually integrates sustainable practices into the current FM practice. The paper is consisted of four main parts. The first part explains the research design and methodology adopted. In following, it presents findings of the first round Delphi survey. Next, section conceptually integrates FM services, practices and sustainable practices into the FM practice. Finally, the paper is disclosed with the conclusions.

2. RESEARCH METHODOLOGY

The study initially involved in an extensive literature review in identifying facilities management (FM) context, FM practice and sustainable practices in relation to HC sector. FM context was reviewed to identify the current FM services and practices. For that, purpose FM related published journals, conference papers were reviewed from 1990 to 2017, in which 10 articles listing the appropriate context of FM was shortlisted and reviewed. Thereafter, HC specific FM practices were reviewed from published materials such as; journals, conference papers and HC specific documents in relation to each of the FM services. Then sustainable practices in relation to each of the FM services and practices were reviewed from 2000 to 2017 through extensive document review. These documents were electronically searched in the search engines with the key words of "sustainable FM practices in HC", "HC sustainable practices" and "HC green practices". Amongst many documents were obtained in which 52 documents [including journal papers (17), conference papers (12), HC guide documents (10), books (4), issue papers (3), green buildings guides (2) and government guides (4)] were examined. These documents were clustered among many fields for example; energy, water, HC waste, quality management and space planning etc focused on individual aspect of sustainability. Amongst those, documents written to aid building operators in meeting sustainability were selected. After the selection of documents, sustainable practices were identified and grouped in terms of its related FM practice depending on the characteristic and feature. This enabled the study to conceptually integrate sustainable practices into the FM practice.

Then, a Delphi survey was conducted among 10 key persons concerning FM practice in HC sector. The respondents who possess an experience above 10 years in FM practice with HC involvement and exposure to sustainability were selected. Thus, the details of the respondents are presented;

2.1. DEMOGRAPHICS OF RESPONDENTS

In terms of the educational background 50% of the respondents had master's educational qualification, 30% had degree in engineering and 20% had degree in management. Considering the experience in the field of FM practice 60% of the respondents had 11 to 15 years of experience, 20% had 1 to 5 years and 10% of respondents had 6 to 10 years and 16 to 20 years of experience. Further to the experience in HC sector, the respondents had 6 to 10 years 40%, 1 to 5 years 30%, 11 to 15 years 20% and 10% had more than 25 years. However, all the respondents had more than 10 years of experience in total despite the experience in FM practice or HC sector they possessed. The following demographic results are presented in graphical method in Figures 1, 2 and 3 respectively.

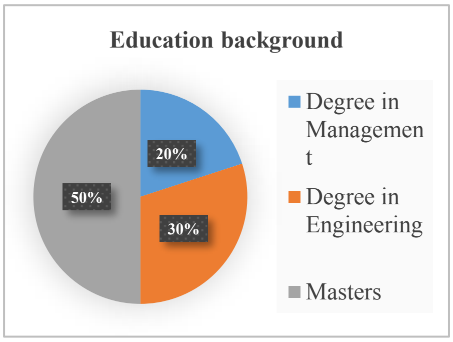

Figure 1: Education background

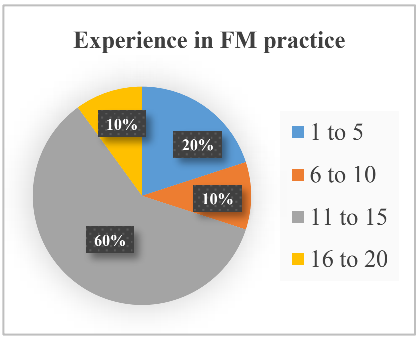

Figure 2: Experience in FM Practice

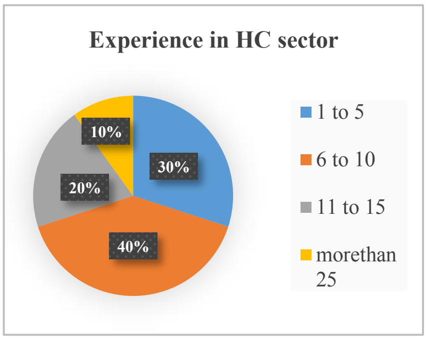

Figure 3: Experience in HC Sector3

This study presents the first round of Delphi survey results which focused on identifying the most important FM services and practices in integrating sustainability. In the design of questionnaire, a five-point Likert scale was employed to quantify responses. The level of significance was based on the respondents' professional judgement on a given scale which consisted of: 1="not at all important", 2= "slightly important", 3="moderate", 4="highly important" and 5="excellently important". In addition the appropriateness of each FM practices in terms of the FM service classification was mapped in the first round based on a scale consisting of: 1= "strongly disagree", 2="disagree", 3="moderate opinion", 4="agree" and 5="strongly agree". Data analysis was conducted using relative importance index (RII) ratings to identify the most significant FM services and practices to integrate sustainable practices. RII value of 0.7 or above are regarded as sufficient (Ikediashi Ogunlana, S. and Ujene., 2012) and the value resulted below were taken further to the subsequent rounds as it did not attain consensus.

3. EXPERT SURVEY RESULTS

This section of the paper presents the findings from the first round of Delphi survey conducted.

3.1. *SIGNIFICANT FM SERVICES IN INTEGRATING SUSTAINABILITY*

11 FM services were identified through an extensive literature review. In essence, Table 1 presents the results attained in the first round of the Delphi survey on the significant FM services in integrating sustainability into the FM practice in HC sector.

Table 1: Significant FM Services in Integrating Sustainability

FM services		**RII**	**Rank**
Building Services and management	BS	0.94	1
Quality management	Q	0.90	2
Space Planning and management	SP	0.90	2
Finance management	F	0.88	4
Risk management	R	0.86	5
Information Technology	IT	0.84	6
Planning and programming	P	0.82	7
Operations management	O	0.78	8
Human Resources management	HR	0.66	9
Real Estate management	RE	0.58	10
Marketing management	M	0.46	11

Delphi survey results revealed that BS as the most important FM service in integrating sustainability in the context of HC sector with receiving RII of 0.94. Similarly, in literature review also BS was frequently reported and considered important. Q and SP identified as equally important receiving RII of 0.90 and identified as the second significant FM services in integrating sustainability in HC sector. However, these FM services were moderately sighted in the literature findings. Furthermore, RE and HR were highly referred in literature review but according to the expert survey these services are identified as not significant in integrating sustainability in the context of HC sector with receiving RII of 0.58 and 0.66. Moreover, marketing management in literature was sighted very rarely and in the view of expert also, it was regarded as not important in integrating sustainability in the HC sector with RII value of 0.46. Accordingly, out of total 11 FM services identified in the literature findings only 8 FM services were considered important in integrating sustainability in HC sector. Thus, the remaining 3 FM services namely HR, RE and M did not reach consensus amongst the expert and intend to be carried forward to the subsequent round to attain consensus of experts. Next section presents the results on significant FM practices in integrating sustainability.

3.2. *SIGNIFICANT FM PRACTICES IN INTEGRATING SUSTAINABILITY*

Table 2 shows the RII value and ranking obtained for the 38 FM practices in integrating sustainability.

Table 2: Significant FM Practices in Integrating Sustainability

	FM practices	**RII**	**Rank**
Q1	- Educating the work force on related standards and procedures	0.96	1
P1	- Strategic Facility Planning (SFP) for HC	0.96	2
Q2	- Deploy quality control and assurance practices with proper standards	0.94	3
BS1	- Maintain building and fabric	0.92	4
BS2	- Housekeeping services	0.92	4
BS3	- Waste management	0.92	4
Q3	- Service tasks standardisation and benchmarking	0.92	4
F1	- Prioritise risk and allocate budget	0.92	4
IT1	- Integration of several FM services	0.92	4
P2	- Facility analyse and synthesize the HC requirement	0.92	4
HR2	- Effectively manage diverse workforce	0.92	4
HR5	- Involve in change management process	0.92	4
R1	- Identifying and detecting risks in HC	0.90	13

	FM practices	RII	Rank
R2	- Assigning values to risks upon it severity	0.90	13
P3	- Long-term, mid-term, annual resource planning of HC	0.90	13
HR3	- Create a learning environment for workforce	0.90	13
BS4	- Run and maintain plant	0.88	17
Q4	- Delivery of consistent high-quality performance	0.88	17
F2	- Manage the finances of the facility function etc	0.88	17
IT2	- Determine different technical requirements of HC activities	0.88	17
HR4	- Conduct performance management periodically	0.88	17
F3	- Budget estimation and cost control	0.86	22
HR1	- Participate in interview panels for multiple positions	0.86	22
SP1	- Involve in space management activities	0.84	24
SP2	- Space allocation, utilisation and relocation	0.84	24
SP3	- Space use audit and monitoring	0.84	24
R3	- Minimize the impact on the patient and the hospital	0.84	24
BS5	- Manage transportation	0.82	28
IT3	- Digitalising the record system Eg: electronic medical record, administrative and financial system etc	0.82	28
F4	- Identify the impact of the transaction on the system's financial statements and ratios	0.8	30
R4	- Create a learning environment for workforce	0.8	30
O1	- Purchasing and procurement control negotiation	0.8	30
O2	- Initiate effective ambulatory Care	0.76	33
RE1	- Lease negotiation and management from clinic space to ambulatory surgery centers (ASC)	0.72	34
BS6	- Catering	0.66	35
M1	- Enhances visibility and image	0.65	36
O3	- Patient management	0.64	37
M2	- Participate in marketing programs, promotions and campaigns	0.63	38

Accordingly, out of the total 38 FM practices the respondents indicated that educating the work force on related standards and procedures and Strategic Facility Planning (SFP) for HC as the most important FM practices in integrating sustainability in the HC sector with receiving the highest RII of 0.96. Following, FM practices namely, deploy quality control and assurance practices with proper standards attained the third important practice with receiving RII of 0.94. As HC sector is vulnerable in spreading diseases and other hazardous substances, maintaining quality achieved the first top priority among the experts' opinion. Moreover, FM practices such as catering, enhances visibility and image, patient management and participate in marketing programs, promotions and campaigns received the least RII value of 0.66, 0.65, 0.64 and 0.63 and identified as not significant in integrating sustainability in the HC sector. Consequently, these practices were intend to be carried forward to the subsequent rounds of Delphi survey to reach consensus among the experts. Therefore, the first round of Delphi survey revealed that, 8 FM services and 34 FM practices were considered important in integrating sustainability in HC sector. This was carried forward in integrating sustainable practices into FM practice in HC sector.

4. INTEGRATION OF SUSTAINABLE PRACTICES INTO FM PRACTICE: CONCEPTUAL VIEW

This section conceptually integrates the finding from the previous sections 3.1 and 3.2 with integrating its respective sustainable practices. FM services and its respective FM practices were crossed checked and mapped for its appropriateness in the first round of the Delphi survey and consensus was reached upon all 38 FM practices. Therefore, all the FM practices classified under the FM services were integrated in accordance to the expert survey opinion. Thereafter sustainable practices were identified through a document review and they were classified under each of the FM practices and FM services depending on the feature and characteristics.

Table 3 presents the conceptual integration of FM services, FM practices and sustainable practices for FM practice in HC sector. In essence, 8 FM services and 34 FM practices were identified as significant in integrating sustainability into the FM practice in HC sector. However, out of the 11 FM service, 3 FM services namely HR, M and RE and its relevant 8 FM practices were considered not significant in the conceptual integration as per the expert's opinion. Therefore, out of the total 34 significant FM practices only 28 FM practices were carried forward in the conceptual integration of sustainable practices into FM practice in HC sector.

Table 3: Conceptual Integration of Sustainable Practice into FM Practice

FM service	FM practices	Sustainable practices
BS	BS1	**s-BS1a**. Improve better indoor environment quality to prevent infection, sick hospital syndrome (SHS) causing headaches, fatigue, eye and skin irritations etc. in hospitals to protect visitors, patients and hospital staffs [1]
		s-BS1b. Improve the acoustic level of HC setting to avoid sleep disruption, awakening, increased hospital stay and rehospitalisation for patients and work pressure, stress, annoyance, increased fatigue, emotional exhaustion and burnout etc for HC staff [2]
		s-BS1c. Maintain good day lighting to stimulate healing environment since exposure to day lighting reduce heart rate, increase activity levels, influence the intake the pain drugs, improve mental health and reduce length of patient stay in HC [3]
		s-BS1d. Use of automated shading and redirecting sun light strategies to improve healing [3]
		s-BS2e. Ensure proper thermal comfort (20°C - 24°C) at general conditions and ensure to provide low temperature during cardiac surgery, usually a higher setting for paediatric surgeries at 17°C or below [4]
		s-BS1f. Preserve heritage Eg: replace "exotic" trees with "native species", encourage cultural practices among staffs [5]
	BS2	**s-BS2a**. Use of proper infection control measures and dust control measures for comprehensive cleaning strategy [6]
		s-BS2b. Deploy Integrated Pest Management strategy to minimise the usage of chemical treatment of eliminating pests [7]
	BS3	**s-BS3a.** Execute the HC waste management plan. [8]
		s-BS3b. Minimise waste [8]
		s-BS35c. Follow appropriate methods such as 3R, 5S system and zero waste strategy etc. [9]
		s-BS3d. Follow appropriate colour coding system for different type of wastes [9]
		s-BS3e. Ensure appropriate onsite, off-site storage and transport of non-hazardous, hazardous waste and medical wastes to avoid any leaks, infections and pollution [10]
		s-BS3f. Treat infectious wastes before final disposal if necessary [10]
		s-BS3g. Select appropriate non incineration technologies combination to decontaminate waste through thermal process, chemical process, irradiative process, mechanical process and biological process [11]
	BS4	**s-BS5a.** Incorporate suitable filtration to trap microbiological pathogens, particulate contaminants and other hazardous substances to remove from the circulating air [12]
		s-BS4b. Prevent nosocomial infection through maintaining differential pressure controls to ensure clean-to-less-clean airflows [12]
		s-BS4c. Maintain proper directional airflow controls to avoid mixing of airborne pathogens [12]
		s-BS4d. Identify applications for energy saving measures in electromechanical installations Eg: HVAC, lighting systems, boilers, gas systems etc. [13]
		s-BS4e. Use of renewable energy sources Eg: solar panels, wind, biomass [13]
		s-BS4f. Conduct energy audits and determine energy usage to ensure efficient energy consumption [14]
		s-BS4g. Use of sensors in applicable perimeter zones to save energy Eg: Day lighting, occupancy sensors, timers, automated shades etc. [15]
		s-BS4h. Identify water conservation opportunities in boilers, cooling towers, kitchen, laundry and sanitary areas etc. [16]
		s-BS4i. Reduce access water usage in medical activities namely surgical scrubbing, dialysis unit, patient care activities, laser cooling, hydrotherapy and birthing pools etc. [16]
		s-BS4j. Consider the amount or type of water used for outside watering Eg: rainwater harvesting, sprinkler timings, plant choice and mulching [16]

FM service	FM practices	Sustainable practices
		s-BS4k. Use of alternative supply sources Eg: boreholes, rainwater harvesting and greywater reuse etc. where water quality is not recommended [16]
		s-BS4l. Reduce avoid pollution through sewage and waste water discharge in HC Eg: introduce Sustainable Drainage Systems (SuDS) [16]
	BS5	**s-BS5a**. Reduce carbon emission and fleet-fuel consumption in fleet management [9]
		s-BS3b. Introduce vehicle sharing, bicycle transport and shuttle services in between HC site [9]
Q	Q1	**s-Q21.** Create awareness among the research managers, doctors and employees about the biosafety requirements [17]
	Q2	**s-Q2a.** Epidemiological advice followed for appropriate water quality at specialist unit such as dialysis unit, neo-natal units, maternity departments and children's units [18]
		s-Q2b. Secure and sufficient supply of nutritious food [19]
		s-Q2c. animal welfare standards are followed in food management [20]
		s-Q2d.appropriate quality are followed in cleaning process [20]
		s-Q2e.high water quality standards and safety are monitored at various application in HC such as for laboratory usage, pharmaceutical purposes, Medical Device Reprocessing purpose and dialysis etc. [21]
	Q3	**s-Q3a.** Carry out disease prevention duties such as cleaning, health-care waste management, hand hygiene and asepsis consistently Eg: comply with the recommended "dwell" time to eliminate the targeted organism [21]
	Q4	**s-Q4a**. Periodically conduct quality audits and check lists [22]
SP	SP1	**s-SP1a.** Usage of various colour themes through incorporating pastel colour, various colour fabric and synthetic leather, colour therapy etc. [23]
		s-SP1b. Use of proper landmark and symbols features to avoid stress of patients [23]
		s-SP1c. Alignment of proper indoor environment to upkeep the indoor environment quality in terms of acoustic, visual and thermal comfort [23]
		s-SP1d. Provide easy visual angle and observation areas [23]
		s-SP1e. Provide distinctive visual differentiation between surfaces such as; ceiling, wall and floors by appropriate means of colour, texture and pattern [23]
	SP2	**s-SP2a**. Dedicated space(s) assigned for segregation and storage of waste [24]
		s-SP2b. Incorporating healing gardens through roof gardens, indoor gardens, aquarium, fountains [18]
		s-SP2c. Provision for view out areas to support healing environment [18]
	SP3	**s-SP3a**. Ensure proper furniture layout arrangements to ensure ergonomics effects, risks and easy handling [18]
		s-SP3b. Arrange waiting rooms to provide more social contacts and increase the length of stay of families and friends [25]
F	F1	**s-F1a.** Avoid supporting and allocating funds against projects that are clearly unsustainable [26]
	F2	**s-F2a.** Evaluating and prioritizing capital investments considering economic, environment and social benefits [24]
		s-F2b. Consider long-term financial forecasting and asset management planning [27]
	F3	**s-F3a.** Introducing green accounting strategies [28]
	F4	**s-F4a.** Consider LCC analysis in all departments [29]
R	R1	**s-R1a.** Conduct environmental infection control in health-care facilities. This allows to predict the measures to prevent infections associated with air, water, and other elements of the environment [30]
	R2	**s-R2a.** Conduct ecological risk assessment periodically. This allows to identify environmental problems in HC and enables to establish priorities, and provide a scientific basis for regulatory actions [31]
	R3	**s-R3a**. Conduct risk assessment in case of any catastrophic event [23]
	R4	**s-R4a.** Maintain a Proof of notification of hazardous substance released to the environment [13]
IT	IT1	**s-IT1a.** Use of centralized system to avoid duplication, repetitive work, in purchasing [32]
		s-IT1b. Introduction of HC building management system to improve energy consumption, carbon dioxide emission, electricity consumption and comfort of patients and occupants [32]
		s-IT1c. Introduce centralised transportation information desk to minimise repetition and avoid emissions to environment [32]
	IT2	**s-IT2a.** Transforming to mobile technologies [33]
		s-IT2b. Introduce live data on available transport options [19]
	IT3	**s-IT3a**. Introduce feed-forward information systems with real-time feedback [34]

FM service	FM practices	Sustainable practices
		s-IT3b. Transforming Electronic Medical Records (EMR) systems to Health Information Exchange (HIE) platforms [34]
P	P1	**s-P1a**. Introduce telecare, home care, video and teleconferencing facilities to reduce care miles, air pollution and to support and care for people with chronic illness living at home [35]
		s-P1b. Collaboration and take remedial action with Municipal authorities to reduce the pollution caused through disposal of waste dumped in landfills [36]
		s-P1c. Plan for reduction of carbon emission from all operational activities of HC considering energy management, fleet management, procurement, and preventative HC etc. [36]
	P2	**s-P2a.** Implement a hospital water safety plan ensuring design, commissioning, operational management, pseudomonas aeruginosa – advice for augmented care units and controlling and monitoring the system [37]
		s-P2b. Plan for HC waste management considering hazardous HC waste i.e. sharps, infectious wastes, pathological wastes, pharmaceutical wastes, chemical wastes, radioactive waste and non-hazardous wastes for individual departments [37]
	P3.	**s-P3a.** Appoint special team on sustainable practices to develop and implement the sustainability plan at HC [16]
O	O1	**s-O1**. Incorporating sustainable procurement strategies in terms of procuring goods and services. This may include practices such as;
		s-O1a. use of fair trade food [30]
		s-O1b. use of biologically and organically produced food [30]
		s-O1c. reduce distance travels from suppliers[30]
		s-O1d. use of less toxic cleaning agents [30]
		s-O1e. Purchase of environment friendly product. Eg: energy saving and efficient appliances, computers, scanners, monitors etc. [30]
		s-O1f. locally produced items [30]
	O2	**s-O3a.** Provide sustainable ambulatory care Eg: patient evidence-based care, reduce patient readmission, enhanced mutual trust with doctors [38]

[1] Thomson *et al*. (2011); [2] Joseph and Ulrich (2007); [3] Boyce (2016); [4] Verheyen *et al.(2011)*; [5] Thompson, Brewer, and Brewer (2002); [6] TEFMA (2004); [7] Dyck *et al*. (2005); [8] Sapkota *et al*. (2014); [9] BREEAM (2014); [10] World Health Organization (WHO) (2016); [11] Kaiser *et al*. (2001);[12] Leung and Chan (2014); [13] Bocken *et al.* (2014); [14] EPTA (2007); [15] Pitt *et al.* (2009b); [16] Priyalal *et al*. (2015); [17] Kumar (2014); [18] Department of Health UK (2013); [19] ACT Government (2010); [20] Sutherland *et al*. (2013); [21] Baker (2012); [22] Kincaid (1994); [23] Kleindorfer *et al.* (2012); [24] Miller (2009); [25] Braveman and Gruskin (2003); [26] Cohen (2007); [27] Green Building Council of Australia (2009); [28] Abigo *et al.* (2012); [29] Kohler and Bauproduktion (2003); [30] Carnero, (2015); [31] Solomon *et al.* (2013); [32] NHS (2015); [33] Lindberg *et al.* (2013); [34] Grossmann, *et al.* (2011); [35] Lindberg *et al*. (2013); [36] Prüss *et al*. (2014); [37] Bonadonna *et al.* (2017); [38] Mccain (2011)

The conceptual integration of FM services, FM practices and sustainable practices comprises of 8 FM services, 28 FM practices and 78 sustainable practices. Amongst all the FM services highest number sustainable practices were identified in BS i.e. 29 numbers in which run and maintain plant (BS4), FM practice comprised the highest number of 12 sustainable practices. Even though BS4, FM practice received 17th rank in integrating sustainability it comprised the highest number of sustainable practices and identified as the most important FM practices in integrating sustainability in the conceptual integration. The second highest number of sustainable practices were identified under SP, FM service of 10 numbers which were unevenly distributed under its relevant 3 FM practices. Similar to the findings of the significant FM services in section 3.1, BS and SP identified to comprise the highest number of sustainability practices and identified as most important FM services in integrating sustainability practices. Furthermore, O had the third highest level of sustainable practices of 9 numbers in which the FM practice, purchasing and procurement control negotiation (O1) had the second highest number of 7 sustainable practices. In accordance to the sections 3.1 and 3.2 results O and its FM practice O1 identified less important receiving 8 and 31 ranking. However, in the conceptual integration O identified as the 3rd important FM service and O1 as the second important FM practice comprising highest number of sustainable practices. Moreover, FM services such as Q, IT, P, F and R consist of sustainable practices varying from 8, 7, 6, 5 and 4 numbers respectively. Among these FM services the least sustainable practices were identified in the R, FM service. However, R was identified as significant in both results in sections 3.1 and 3.2 receiving the fifth and fourteenth rankings respectively whilst in the integration of sustainability practices it is the least important FM services comprising of least number of sustainability practices. Thus, this added to the total 78 number of sustainable practices distributed under 28 FM practices and 8 FM services. This will be further carried forward to the subsequent rounds of Delphi survey to map the appropriateness and identify the significant sustainable practices in effective integration of sustainable practices into FM practice in HC sector.

5. CONCLUSIONS

For effective integration of SFM practice in HC, integration of FM service, FM practices and sustainable practices were identified vital. Therein, this study identified 8 FM services such as; BS, SP, O, Q, IT, P, F and R as the most significant in integrating sustainability in the HC sector through a Delphi survey in which BS achieved the most important FM service. However, M, HR and RE services did not reach consensus and carried forward to reach consensus to the subsequent round. Then HC specific 28 FM practices were identified as the most significant practices in integrating sustainability in which educating the work force on related standards and procedures and Strategic Facility Planning (SFP) for HC achieved the most important FM practice. Out of the total 38 FM practices only 28 was identified as most significant in integrating sustainability in the HC sector. Thereafter this study conceptually integrates FM services, FM practices and sustainable practices into the FM practice in HC sector.

The conceptual integration of sustainable practices into FM practice comprises of total of 78 sustainable practices under its related FM services and FM practices. This was classified in terms of its context and feature in which highest number of 29 sustainable practices were identified in BS area. Moreover, the highest number of sustainable practices were identified in terms of FM practices namely; BS4 (12), BS5 (7), O1 (7), BS1 (6) and Q2 (5). In addition, Q1, Q2, P3, F1 to F4 and R1 to R4 FM practices consisted of the least number of 1 sustainable practice. According to the survey findings BS4 FM practice received 17th ranking whilst in integrating sustainability practices it comprised the highest numbers. Similarly, in survey findings O1 FM practice received 31 ranking whilst in integrating sustainable practices it consist 7 practices and received the second important FM practice. This shows the different findings from survey and conceptual integration of sustainable practice in FM practice in HC sector. Therefore, as way forward of the study, the findings will be carried forward to the subsequent rounds of the Delphi survey in determining the most significant sustainable practice in integrating sustainability into FM practice in HC sector. This will enable the industry practitioners to identify the most important SFM practice with respect to each of the FM services and practices in HC sector.

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KEY PERFORMANCE INDICATORS FOR MEASURING THE PERFORMANCE OF FACILITIES MANAGEMENT SERVICES IN HOTEL BUILDINGS: A LITERATURE REVIEW

W.D.I.J. Fernando*, D.M.P.P. Dissanayake, N.H.C. Manjula and A.S. Weerasinghe

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

People travel across the world for leisure, business, and relaxation purposes and seek short term or long-term accommodation facilities. With the increase in globalisation and rapid development in technology, the hospitality industry is changing quite momentously in order to respond to the changing needs and expectations of the travellers. Similarly, hotels as one of the main pillars of the hospitality industry, have an important role in a country's economic development. Subsequently, Facilities Management (FM) has become a demanding profession in developing and developed economies, which maximise profits while reducing operation and maintenance costs. In this context, Facilities Managers support the functionality of non-core activities of the hotel sector in line with the core objectives. However, there is an inadequate performance in building services and maintenance of hotel buildings, which lead to loss of productivity, a reduction in profitability, a loss of clients and a general negative company image. To this end, the Performance Measurement (PM) is an essential requirement in hotel sector to increase the performance of FM services. Therefore, this paper synthesises the FM performance based on Key Performance Indicators (KPIs) that indicates how well the organisation is performing in accordance with their strategic objectives and goals. Further, the paper discusses the requirement of PM for FM services in hotel sector. Ultimately, a set of KPIs have been identified based on the available literature in order to measure the performance of FM services in hotel buildings.

Keywords:*Facilities Management; Hotel Sector; Key Performance Indicators; Performance Measurement.*

1. INTRODUCTION

Facilities Management (FM) is a profession, which encompasses numerous disciplines in order to pursue functionality of the built environment while integrating people, place, process, and technology (International Facilities Management Association [IFMA], 2009). The scope associated with the FM typically include a wide range of functions and support services including engineering services, real estate management, space planning, waste management, safety and security, etc. (Alexander, 2009; Adnan & Farida, 2015). Due to the complex scope of FM in an organisation, positive or negative influences of FM services contribute to successful nor failure in any kind of organization (Gilleard & Yatling, 2009). When it comes to the hotel sector, FM services are critical and complex in nature (Priyangani, 2009). Hence, the prime objective of a hotel business is to satisfy needs of the guests. Subsequently, many noncore services of hotels which are under the scope of FM are directly contribute to achieve its prime objective, guest satisfaction including heating venting and air conditioning, electrical service, plumbing service, lift and escalators, information and telecommunication, safety and security service, waste management and landscaping are contributing to achieving its prime objective (Priyangani, 2009). In the meantime, a continuous PM is an essential need for facility managers to measure the performance and achieve productivity of FM services supplied (Varcoe, 2007; Favier & Paul, 2009). However, existing literature disclosed that service quality of FM services has been decreasing in hotel sector due to less focus on compliance, continual improvement, outdated technology, lack of training, inferior quality materials of FM companies (Fernando et al., 2014). All above reasons are due to

*Corresponding Author: E-mail – devsayura59fernando@gmail.com

the absence of proper KPIs for FM services. Therefore, the establishment of a comprehensive performance review system will be a reference to such hotel buildings to set performance indicators in order to upgrade the performance of FM service providers. On the other hand, it is beneficial to the FM service provider to evaluate their own performance and to deliver the service according to agreed service levels. Therefore, the aim of this paper is to develop KPIs for measuring performance of FM services in hotel buildings based on existing literature. In order to achieve the aim of the research, this paper first underlines the concepts of FM, PM and KPIs and explains the requirement of PM in FM services and finally develop a set of KPIs which can be used to measure the performance of FM services in hotel sector.

2. METHODOLOGY

A comprehensive literature review was used as research methodology for this research paper. Literature review was carried out on a broader perspective with the purpose of being familiarised with the subject areas of the research study while holding the focus on research problem. The background study took the attention of journal articles, online journals, e-books, web sites, electronic library database and other publications. KPIs for measuring performance of FM services in hotel sector developed at the end by bringing in literal arguments.

3. FM SERVICES IN HOTEL SECTOR

Most of FM definitions highlight the link between the concepts of FM, productivity, PM and Business growth (Alias et al., 2014). Eric (2004, 2008) discussed IFMA's research report in which a total of 41 FM roles and responsibilities are classified under eight major headings; real estate management, maintenance management and budgeting, space planning, service installation, building handover, architecture, building operations, Standard Operating Procedures (SOP), building service contract agreements. There are several models of FM including in-house FM, FM bundle service supplier, managing agent and total FM supplier (Kurdia et al., 2011). FM has achieved an iconic image in global building management sector through the past decade while expanding the FM market of the world (Dimyadi & Prasanezad, 2014). In addition, the establishment of professional institutions in the United Kingdom, Japan, and Australia had enhanced the value of FM profession around the world (Nascimento & Quinello, 2013). FM is widely spread throughout different types of building facilities including shopping complexes, industrial facilities, hotel facilities, hospital buildings and educational facilities (Damgaard et al., 2009). Considering about the hotel sector, FM and Engineering services are complex and critical in hotel sector (Priyangani, 2009). FM services can be divided into two main categories as hard FM services and soft FM services (Atkin & Brooks, 2009) as shown in below Figure 1.

FM Services		
Hard FM	**Soft FM**	
Mechanical systems and services: HVAC, boilers, hot/cold water systems, drainage etc. **Electrical systems and services**: main distribution system, lighting systems; emergency and critical systems; heating/cooking; IT networks/server rooms; standby systems and supplies. **Public health services:** plumbing; drainage; sanitation; water supplies **Control systems:** comfort control; alarm/fire monitoring; security – access/egress; maintenance systems; energy monitoring; energy management. **Utility services**: electricity; solar, wind, ground, coal-fired, nuclear, hydro, combined heat and power (CHP) systems; oil; gas; water; air; waste/sewerage. **Property management;** **Fabric maintenance;** **External areas, grounds and landscaping.**	Computing equipment and data services Reprographics and printing services Stationery and consumables purchasing Newspapers and publications services Wireless, fixed and mobile telephony and broadband services Information centres, common area notice boards Signage and legal notices Helpdesk services First-aid services Occupational health services Fabric maintenance services Cleaning and housekeeping services Vending of personal hygiene consumables Catering and vending services	Security and business continuity services Car parking, car valet and car servicing schemes. Green travel plan services, e.g. shuttle buses, bicycle share schemes and car sharing services Company vehicles and car fleet management Sports, fitness and leisure facilities Merchandising, retail and Internet shopping services Personal purchases (energy, stationery, cars). Business travel services Residential accommodation services Landscaping and grounds maintenance Internal planting Office furniture and equipment Secretarial services Library services

Figure 1: FM Services
Source: Alexander (2009) and Atkin and Brooks (2009)

4. PERFORMANCE MEASUREMENT OF FACILITIES MANAGEMENT SERVICES IN HOTEL SECTOR

In order to align with the rapidly developing tourism sector, hotels need to comply and maintain proper standards to build their image and compete with the other hotels in the sector (Jayasinghe, 2015). Kavrakov (2015) defined PM as a process which company assesses the delivery of its goals and objectives within the organisational activities. It helps to achieve customer satisfaction, monitor progress, benchmark process and activities, and drive change (Enoma & Allen, 2007; Pit & Tucker, 2008). Furthermore, Amaratunga and Haigh (2008) identified some positive effects of PM in FM and they are focus people's attention, business improvement, improve customer satisfaction, increase productivity, align operational performance with strategic objectives, improve people satisfaction, align people behaviours towards continuous improvement and improve reputation. The below Figure 2 shows the crucial need and importance of performance review of FM services and it further explains the need for measure performance to influence performance.

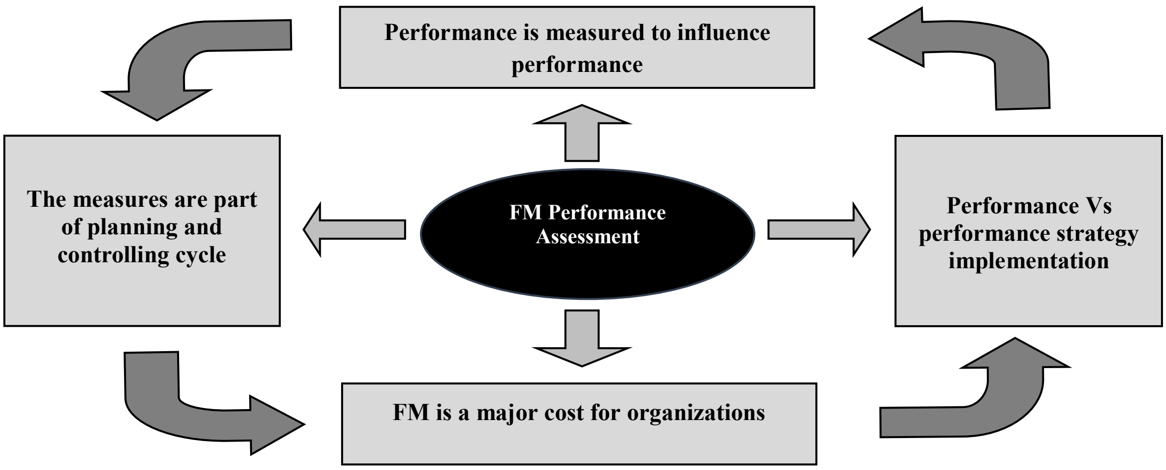

Figure 2: Performance Assessment

Source: (Amaratunga and Haigh, 2008)

India, Singapore, Dubai, and several other countries have increased their profitability of hotels by the use of PM as a strategic tool (The Travel and Tourism Competitiveness Report, 2015). Priyangani (2009), Shohet (2006); Schwarz et al. (2010) and several other researchers have developed frameworks for PM of FM services using different approaches in different industries. However, there are limited researches carried out for hotel sector with the aim of measuring performance of FM services. In this context, PM is essential as it enables to increase the performance of FM services. Generally, around 60-85% of total building life cycle cost is spent in the operation and maintenance phase, the maximum consumption of energy and cost of its life cycle (Eastman et al., 2008). The optimization of the resources could achieve by efficient performance of the buildings with efficient FM (Lewis et al., 2010). Therefore, continuous PM is required to increase the efficiency, reduce the operational cost and prolong the lifespan of the building (Jaaskelainen, et al., 2012). Facility managers require performance information to monitor and control maintenance process and results and provide indication towards possible requirements for improvements to the facility (Alsyouf, 2007).Therefore, the proper performance level of FM must be carried out within hotels (Aryee, 2011). In order to carry out a proper performance level, it is necessary to measure the existing level (Jayasinghe, 2015). In that case requirement of PM in FM takes place hotel trade (Priyangani, 2009).

5. KEY PERFORMANCE INDICATORS FOR MEASURING PERFORMANCE OF FACILITIES MANAGEMENT SERVICES

5.1. DEFINING KPI

According to Kvarakov (2015), KPIs are the most valuable instruments of PM. According to British Institute of Facilities Management (BIFM, 2014), KPIs are set of financial and non-financial measures of a contractor's performance relative to the critical success factors of FM service. Further, the decisions regarding how to upgrade the performance of a facility are decided based on data analysis (Cooper, 2012; Neiger et al., 2012). Hence, well-defined KPIs can potentially contribute the determination of performance gaps, between desired and current performance, and can show an indication of progress towards eliminating the gaps (Muchiri *et al*., 2009). In recent years, some research efforts have been made for the introduction of the KPI methodology into the FM discipline (Meng and Minogue, 2011). For example, Shohet (2006) has introduced eleven performance indicators for strategic maintenance of healthcare facilities. Further, the KPIs are accurate measures for the selection and comparison of FM service providers while communicating a clear description of desired outcomes and how they will be identified and controlled (Shohet, 2006).

In addition, KPIs are required to be linked to the organisational strategy and after mapping organisational strategy KPIs can be listed out to track progress to improve and manage performance (Liu, 2013). Further, when considering hospitality organisations and their workers, it emerges all the more crucial to establish strategic goals, determine the correct KPIs are directly dependent on an understanding of what is important to the hotel (Liu, 2013). Leavy *et al.* (2014) stated that KPIs should be initially designed to empower employees while feeding them with the relevant important information to a learning process. This facilitates to enhance the decision-making process and results in upgraded performance and the designing process of KPI's initially start with outlining the Key performance questions under each strategic objective. In the hotel industry, KPI should be facilitating employees with clear aims and objectives, coupled with a basic understanding of how they relate to the overall organisational success (Falite, 2013). Moreover, KPI and PM are good practices especially within the hotel industry and the hospitality industry to follow a series of standardized KPI to monitor, to improve and to benchmark performance (Falite, 2013).

5.2. KPIS FOR MEASURING PERFORMANCE OF FM SERVICE IN HOTEL SECTOR

Different researchers have come up with literature related to KPIs for FM services. By conducting an in-depth review of the literature, 82 KPIs were identified from fifteen (15) literature sources. The highest amounts of KPIs (16) have identified under mechanical, electrical and plumbing service and the lowest amount of KPIs (9) are for car park management. Previous studies have given more importance to preventive maintenance schedule, documentation, health and safety aspects in identification of KPIs. The identified KPIs with the respective source have been shown in Table 1.

Table 1: KPI for Facility Management Services of Hotel Buildings

KPI	**Reference Source**														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Mechanical, electrical and plumbing service															
Planned preventive maintenance as per schedule	√			√	√	√	√		√		√	√		√	
Provide operation and maintenance records	√		√		√	√	√	√	√		√	√		√	
Provide & support a continuous helpdesk service	√				√	√	√	√	√		√	√		√	
Manage and undertake reactive operations within service level agreement or SOP	√								√		√	√			

Attend management meetings & provide relevant FM information on time	√		√			√		√		√				√			
Adherence to training & awareness			√			√		√						√			
Staff attendance							√							√			
Use of personal protective equipment and signage		√						√				√		√		√	
Work request response rate	√							√						√			
Store handling					√		√										
Breakdown rate	√	√				√	√	√									
Accurate budgeting plan	√			√		√		√				√		√			
Implementation of energy management and sustainable practices								√						√			
Hazardous material management		√						√						√			
Acceptable operational conditions and parameters				√		√		√				√		√			
Issuing of work permits for required work with risk		√										√		√			
Fire detection and protection service																	
Adherence to fire training and awareness								√						√			
Attend management meetings and provide relevant FM information on time	√				√	√		√						√			
Planned preventive maintenance as per schedule	√		√				√	√									
Provide operation and maintenance records	√		√		√	√		√						√			
Acknowledge and monitor fire alarms		√						√				√					
Acceptable operational conditions and parameters of fire pumps and equipment		√	√			√	√	√						√			
Refilling of fire extinguishers according to schedule								√						√			
Fire incident management and reporting								√						√			
Compliance with local statutory requirements	√		√					√					√	√		√	
Complaints handling	√							√					√	√			
Accurate budgeting plan				√					√		√			√	√		
Health, safety and security service																	
Compliance with local statutory requirements & personal grooming											√			√	√		√
Continuous service to ensure a safe physically secure environment for guests, staff, visitors and building assets					√			√					√				
Manage community violence						√							√	√			

Monitor and acknowledge immediately all alarms, panic alarms, and emergency calls.								√			√	√	√	√
Hold and maintain administration records	√		√		√			√	√		√	√	√	
The site is to be patrolled as per contract and records to be maintained							√						√	
Adherence to training and awareness					√			√		√	√	√	√	
Attend monthly meetings and provide relevant information on time including the monthly report to management								√		√			√	
Incident management and reporting								√					√	
staff attendance											√		√	
Locating and reporting visually identified building issues to responsible persons or parties						√				√			√	
Complaint handling								√					√	
Provide accurate budgeting plan						√		√		√			√	
Housekeeping and waste management														
Adherence to preventive maintenance schedule	√			√	√		√	√			√		√	
Compliance with local statutory requirements	√	√			√		√	√			√		√	
Provide maintenance records	√				√			√			√		√	
Use of personal protective equipment and signage by staff		√				√		√			√		√	
Attend monthly management meeting and provide the monthly report	√				√								√	
Staff attendance				√			√							
Complaints handling	√	√									√		√	
Accurate budgeting plan	√			√		√					√		√	
Adherence to training and awareness					√		√	√			√		√	
Use of sustainable materials and practices								√					√	
Work request response rate	√				√		√							
Car park management														
Adherence to preventive maintenance schedule											√		√	
Compliance with local statutory requirements											√		√	
Operation and management of hotel Shuttle service		√											√	
Staff attendance											√		√	
Incident management and controlling								√			√			

Provide inspection reports	√											√			
Usage and good condition of signage								√							√
Complaints handling								√							√
Attend monthly management meeting and provide the monthly report					√			√							√
Cleanliness of the car park								√							√
Civil work and refurbishment															
Adherence to preventive maintenance schedule	√			√	√		√	√				√			√
Compliance with local statutory requirements	√	√			√		√	√				√			√
Provide maintenance records	√		√		√			√				√			√
Use of personal protective equipment and signage by staff		√				√		√				√			√
Attend monthly management meeting and provide the monthly report	√				√										√
Staff attendance				√			√								
Complaints handling	√	√										√			√
Accurate budgeting plan	√			√		√						√			√
Adherence to training and awareness								√				√			√
Use of sustainable materials and practices								√							√
Work request response rate	√				√		√								
Asset management and space planning															
Compliance with local statutory requirements	√		√					√				√			√
Availability of updated asset register	√					√		√				√			
Availability of assets labeling process												√			√
Asset life cycle planning for critical assets															√
Availability of asset management strategy and plan								√							
Availability of asset positioning indicators												√			√
Accurate budgeting plan						√		√							√
Asset data recording and reporting												√			√
Efficiency of asset utilization					√							√			
Ensure safety of assets		√						√							√

1- Muchri et al. (2009)
2- Nestic et al. (2013)
3- Nascimento and Quinello (2013)
4- Muchri et al. (2009)
5- Adnan and Farida (2015)
6- Srivastava and Maitra (2016)
7- Crick and Spencer (2010)
8- BIFM (2014)
9- Rimbalova and Vilcekova (2013)
10- Shohet (2006)
11- Alexander (2009)
12- University of North Western (2017)
13- Kavrakov (2015)
14- IFMA (2009)
15- Lockyer (2013)

6. CONCLUSIONS AND WAY FORWARD

There is a rapid development in hotel industry in Sri Lanka. Subsequently there is a lack of performance and quality issues in hotel buildings due to unavailability of PM system for FM services. Although there is a critical requirement of PM system for FM. KPI development for FM services can be identified as a solution for above mentioned issue. Therefore, 82 KPIs have identified for FM services in hotel sector through 15 literature sources. Ultimately prioritization of above KPIs and develop a performance improvement strategy for above-mentioned KPIs can be identified as further research areas related to this research.

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LIFE CYCLE COST COMPARISON OF LEED CERTIFIED AND CONVENTIONAL OFFICE BUILDINGS IN SRI LANKA

M.S. Soujanya* and H.A.E.C. Jayasena

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Green buildings are emerging concept to Sri Lankan construction industry. Although with a slow uptake, office building development is currently trending towards green buildings in the country. Lack of knowledge of the developers about advantages of green buildings in terms of the life cycle cost appears to be the largest obstacles which hinder green buildings in the country. In this context this study aims to compare the Life Cycle Cost of LEED certified office building with conventional office building in Sri Lanka in order to raise awareness of the advantages of green buildings mainly in terms of life cycle cost savings. Case study strategy was employed with semi-structured interviews and document survey as the data collection method. An expert survey was conducted to identify the life cycle cost components which are applicable to Sri Lankan context. Life Cycle Cost Analysis was carried out to evaluate the cost savings of green building over conventional building using Net Present Value method. The findings of this study reveal that although the construction cost of green building 5.33% higher of conventional building the cost is saved through operation and maintenance cost.

Keywords: *Green building; LEED certified building; Life Cycle Cost; Office buildings; Sri Lanka.*

1. INTRODUCTION

Construction activities have been accused for continuous and excessive consumption of global natural resources and causing a significant negative impact on environment during construction and operation of the construction industry (Zhang, Wang, Hu, & Wang, 2017). According to Neyestani (2017) and Birkeland (2014) green or sustainable design is the best way to mitigate the negative impact of construction industry on the environment. Green building (GB) is a concept which promotes sustainable build environment (Vyas & Jha, 2017; Evans, Strezov, & Evans, 2015; Chan, Qian, & Lam, 2009; Watkins, 2009; Sharrard, Matthews, & Roth, 2007; Teixeira, 2005; Cole, 2000). Although GBs are a way of reducing the negative impacts on environment, construction cost of GB is a matter of concern for the developers (Ahn, 2010).

However, there are evidences which show that Life Cycle Cost (LCC) of GBs is lower compared to the conventional building (Gou & Lau, 2014). LCC of building includes the total cost of a building during its lifetime, including the costs of planning, design, procurement, operations, maintenance and disposal, less any residual value (Madushan, 2012). According to the study of Bombugala and Atputharajah (2010), GB construction cost is 20-25% higher than the traditional buildings but over the entire life of the building 30-40% cost is reduced in operational cost of the GB building. Further, Weerasinghe and Ramachandra (2017) prove that the construction cost of green industrial manufacturing building is 28% higher than the conventional building while the running cost is 39% lesser than conventional building.

Lack of knowledge about the LCC of the GBs acts as a great barrier for GBs in Sri Lanka (Abeynayake, 2010). According to the United States Green Building Council's (USGBC) project directory, 38 buildings in Sri Lanka have achieved LEED certification in different categories. Among them 18 industrial and manufacturing buildings, 7 office buildings, 6 lodging, 3 retail building, 2 higher education centres, 1 laboratory and 1

*Corresponding Author: E-mail – sayinesoujanyam@gmail.com

warehouse and distribution. This paper compares the Life Cycle Cost of LEED certified office building with conventional office building in Sri Lanka.

2. LITERATURE REVIEW

2.1. OFFICE BUILDING AND ITS IMPACT TO THE ENVIRONMENT

The control of environmental impacts from construction of building has become a major issue to the non-profit organization (Shen & Tam, 2002). Further, Teixeira (2005) and Shen and Tam (2002) has pointed out that the construction process usually results in negative impact to the environment i.e. extraction of environmental resources, production of waste, extensive consumption of natural resources and pollution to the living environment. Globally, in 2010 buildings accounted for 32% of total global energy use and 19% of energy-related Green House Gas emissions.

2.2. GREEN BUILDING CONCEPT

GBs are considered as one of the most effective concept of sustainable development (Low, Gao, & Tay, 2014; Liu, Li, & Yao, 2010). GB is a developing concept of environmental friendly building construction and the rating system for measuring the negative impact of construction towards its environment (Abeynayake, 2010). Vyas and Jha (2017) and U.S. Green Building Council (2009) identified efficient energy usage, water conservation, high quality inner spaces, and non-toxic gas emissions and recycled material usage as the environmental benefits of GBs. Further GB reduces the negative impacts through implementing improved site locations, design, construction, operation, maintenance, disposal and use of recycled and eco-friendly materials throughout its life cycle (Neyestani, 2017; Kibert, 2013).

2.3. GREEN BUILDING RATING SYSTEMS

According to Allen, et al., (2016) the aim of GB rating systems is, to reduce the negative impact of buildings and to improve the occupant health by providing design credits for adopting green design, operation and maintenance. Further, Ali and Nsairat (2009) stated that it produces significant long-term benefits for building owners and occupants, limiting environmental impacts, creating healthier and more productive places and reducing building operation cost.

Moreover, Bayraktar, Owens, and Zhu (2011) and Tatari and Kucukvar (2011) stated that GB rating systems aims to produce more environmental friendly buildings by using set of standards to evaluate the environmental performance of buildings by influencing the design and construction elements and process of building. GB assessment tools usually considers the site, water, material, energy and indoor environment quality and other attributes to measure the performance of the buildings (Gou & Lau, 2014). The following Table 1 presents the different GB rating systems used worldwide to rate the GBs. These rating systems are developed by respective GB council of the respective country.

Table 1: Worldwide Green Building Rating Systems

Rating Systems	Country of Origin
Building Research Establishment Environmental Assessment Method (BREEAM)	Britain
Leadership in Energy and Environmental Design (LEED)	USA
GB Tool	Canada
Comprehensive Assessment System for Built Environment Efficiency (CASBEE)	Japan
ESCALE	France
Hong Kong - Building Environment Assessment Method (HK-BEAM)	Hong Kong
National Australian Built Environment Rating System (NABERS)	Australia
DGNB	Germany
GREENSL®	Sri Lanka

2.4. LEED CERTIFICATION

United States Green Building Council (USGBC) developed LEED GB rating system to provide standards for environmentally healthy design, construction and operation (Green Building Council Sri Lanka, 2011). USGBC (2009) defines LEED as "a voluntary rating program, whose goal is to evaluate environmental performance from the whole building perspective over the building's lifecycle, providing definitive standard for what constitutes a GB". LEED is triple bottom line in action, promoting people, planet and profit (Zhang, Wang, Hu, & Wang, 2017).

LEED rating system is the most popular rating system in the world. Although Sri Lanka has GREENSL® Green Building Council Sri Lanka (GBCSL) decided to follow LEED rating system (Bombugala & Atputharajah, 2010). Similarly, other countries also use LEED as a standard rating tool, as it is widely used and globally recognized as significant assessment system among the other GB rating system (SGS Economic and Planning PVT LTD, 2008). According to the USGBC (2017) report, LEED has been recognized as the most widely used 3rd party certification for GB with approximately 2.2 million square feet being certified daily.

2.5. LEED CERTIFIED GREEN BUILDINGS IN SRI LANKA

There are only seven LEED certified office buildings in Sri Lanka (USGBC, 2017). Hatton National Bank (HNB) Jaffna, HNB Nittambuwa, Orion City Anton Building, Bureau Veritas consumer product service, HSBC head office, Logistics Park and Dialog Axiata PLC corporate head office are the seven buildings.

2.6. LEED CERTIFIED OFFICE BUILDINGS

The green design of office buildings includes finding the balance between the structure and the sustainable environment. Following are the benefits of LEED certified green office buildings:

- Reduced running costs by reducing energy costs
- Reduced health and safety risks to occupants from Sick Building Condition
- Lower absenteeism and improved productivity
- Positive image about the organization
- Higher rent due to more attractive building

Therefore, this research was carried out to compare the cost savings in LEED certified office buildings in Sri Lanka compared to conventional office building.

2.7. LIFE CYCLE COST ANALYSIS

There are several definitions for LCC. Widely used definition in the construction industry is given by ISO 15686 as the "total cost of a building or its parts throughout its life, including the costs of planning, design, acquisition, operations, maintenance and disposal, less any residual value" (Pelzeter, 2007). Wang, Rivard, and Zmeureanu (2005) defined life cycle of building as "The life cycle of buildings covers all processes from natural resource extraction, through material production, construction and operation until demolition, maintenance is usually required the operation phase while transportation is an activity associated with most other phases".

Moreover, LCC is defined as the summation of costs from inception to disposal of a building. Further, LCCA is defined as a method for calculating the entire cost of the building over its life time. LCC is the addition of all the cost of building over its life time including initial cost, running cost and demolition cost.

In addition, the following Figure 1 presents the stages of LCC proposed by Royal Institute of Chartered Surveyors (RICS) in Life Cycle Cost professional guidance (RICS, 2016).

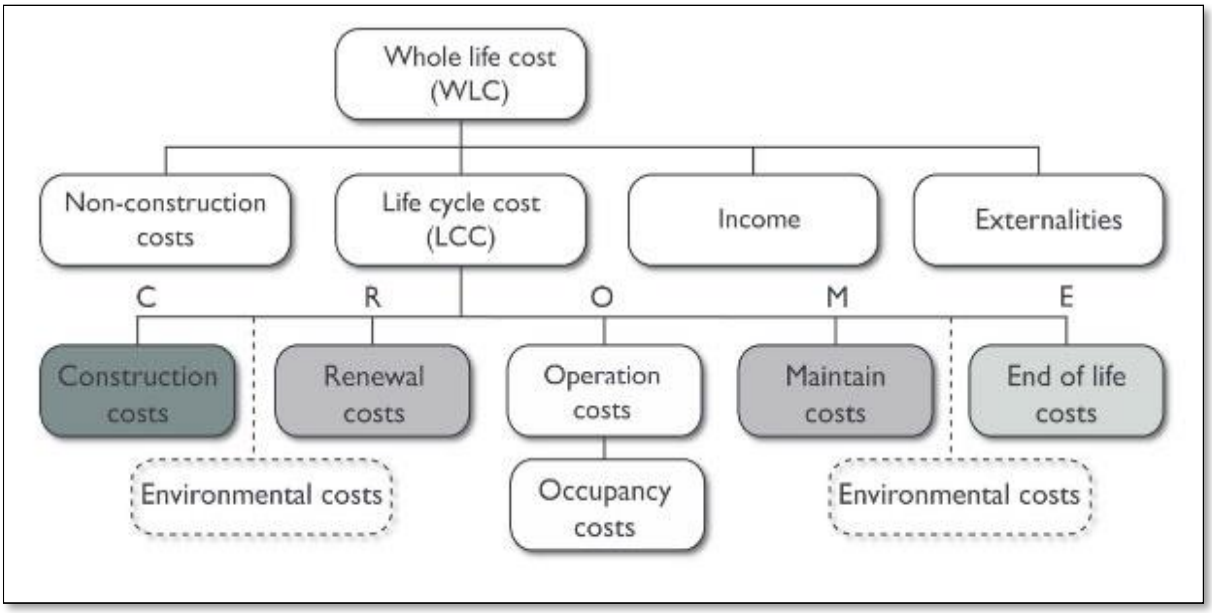

Figure 1: Stages of LCC of by RICS

According to RICS (2016), initial costs includes: site costs, opportunity costs, finance charges, professional fees, construction and infrastructure costs, tax allowances, statutory charges, development grants, planning gain and third party costs. Further, land acquisition cost, design cost and construction cost is identified as the initial cost of buildings.

Further, maintenance costs includes: redecoration, periodic inspection activity, periodic maintenance and component replacement activities, unscheduled corrective and responsive maintenance, planned and preventative maintenance and component replacement (RICS, 2016).

The following are the operational cost components identified in RICS (2016): cleaning and janitorial services, utilities, security, staff engaged in supporting the occupiers, waste management and disposal, property management of operation and occupancy, insurances, and taxes.

End of life costs specifically includes disposal and demolition, but may include residual values (RICS, 2016). Residual value is the value of the building at the end of the study period or at the life cycle period.

2.8. *NON- COST FACTORS AFFECTING THE LCC OF OFFICE BUILDINGS*

The building type, local climate, study period and number of stories affect the financial benefits from GBs. The longer the study period, the greater the energy savings and lower the LCC. Further, the following were identified as the non-cost factors affecting the accuracy of LCC of office buildings:

- Number of stories
- Type of building
- Gross floor area
- Project life
- Location
- Roof types
- Foundation types
- Number of elevators
- Type of structure
- Inflation rate

2.9. *SENSITIVITY ANALYSIS*

Life Cycle Cost Analysis (LCCA) involves the uncertainty in the assumptions i.e. future inflation rates and the anticipate life of the component or facility (Cole & Sterner, 2000). Therefore, economic risk assessment, either probabilistic approach or the sensitivity approach, can be used to reduce uncertainties in LCCA. Sensitivity analysis examines how LCC is influenced by changes in some of the variables (Cole & Sterner, 2000). Sensitivity analysis is used during model development, when the effects of several input parameters need to be analysed (Babashamsi et al., 2016).

3. RESEARCH METHODOLOGY

It was identified that mix method where both the qualitative and quantitative approaches are used to address the research questions was the best method for this study because the case study was chosen to carry out the qualitative approach and LCC calculation was selected to carry out quantitative approach. Due to the limited research conducted relating to the LCC of GBs in Sri Lanka, the case study analysis was selected to carry out qualitative approach. Interviews and document review was selected as the most reachable and reasonable data collection tools due to the nature of this research.

Content analysis and Life Cycle Cost Analysis were used as the data analysis techniques. In this research only four numbers of expert interviews were carried out to gather data, because few expertise are there in Sri Lanka with green building knowledge. Semi structured interview was select as one of the data collection tools for this research because the knowledge about GBs are less and only few researches were carried out in Sri Lanka relating GBs. Through semi structured interview the maintenance period, maintenance method, life time of the building, non-cost factors affecting the LCC of office buildings were collected from the selected buildings. As the aim of this research is to compare LCC between GB and conventional building, document survey was conducted for gathering life cycle cost details from the building owners.

4. RESEARCH FINDINGS AND ANALYSIS

4.1. FINDINGS OF EXPERT SURVEY

The most appropriate LEED certified green office building among the LEED certified green office buildings in Sri Lanka was selected for the case study through expert survey. There are 7 out of 38 LEED certified office buildings in Sri Lanka. Further, the LCC components which are applicable to Sri Lankan construction industry were identified.

Table 2: Expert Survey Respondents' Details

Respondents	Profession	Designation	Experience
E1	Architect	Project Consultant	15 Years
E2	Architect	Green Consultant	30 Years
E3	Engineer	Chief Executive Officer	15 Years
E4	Architect	Project Manager/ Green Consultant	32 Years

According to the findings of expert survey, the following Life Cycle Cost components were identified addition to the cost components identified in the literature review which are suitable to Sri Lankan context.

Table 3: Expert Survey Findings

Construction cost	Operation Cost	Maintenance Cost
Land acquisition cost	Administration costs	Electrical appliances & fittings
Solar tubes	Insurance	External works
Water treatment plant		Minor unscheduled maintenance
Eco roof		Minor scheduled maintenance
		Solar panels
		Eco roof
		Water treatment plants

4.2. FINDINGS OF SEMI-STRUCTURED INTERVIEW

The semi- structured interviews were analysed based on content analysis, through which the non-cost factors affecting the LCC of an office building in Sri Lanka were identified. Details of the semi-structured interview respondents are given in Table 4.

Table 4: Semi-Structured Interview Respondents' Details

Respondent	Profession	Designation	Experience
LEED Certified Office Building			
R1-C1	Engineer	Maintenance Engineer	9 Years
R2-C1	Architect	Green Consultant	30 Years
Conventional Office Building			
R1-C2	Engineer	Maintenance Engineer	25 years
R2-C2	Manager	Maintenance Manager	10 years

According to the findings of semi-structured interview, type of building and the project life are the non-cost factors which affect the LCC of office building in Sri Lanka. According to the Figure 2, foundation type of the building has the least impact on the LCC of an office building. Addition to the type of building and project life, gross floor area, location, roof types and type of structure have significant impact on the LCC of an office building in Sri Lanka.

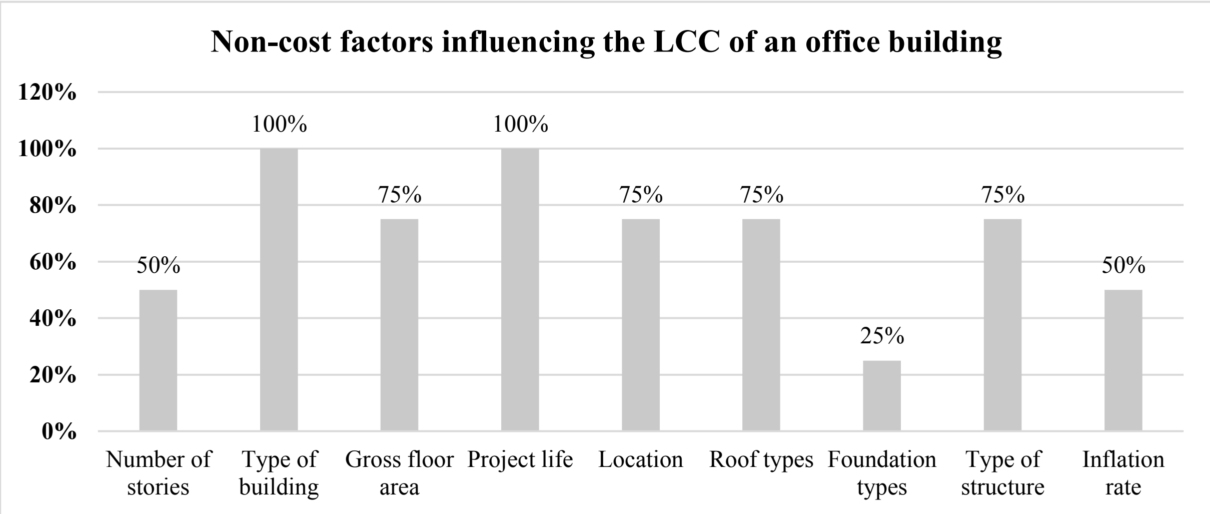

Figure 2: Non-cost Factors Influencing the LCC of an Office Building in Sri Lanka

4.3. LIFE CYCLE COST ANALYSIS FINDINGS

The case study was focused on LEED certified office building and conventional office building with similar physical and performance characteristics considering the year of construction and gross floor area. Case study analysis was carried out selecting two building projects. The LEED certified building was identified through expert survey and finally selected the conventional building with similar characteristics of LEED certified building. The analysis was carried out within the case and the results were compared with the other case. Document review was carried out to collect the actual construction, operation, and maintenance cost details from the cases.

The selected two projects were leading bank in Sri Lanka. Selected GB is the 1st LEED gold certified bank in Sri Lanka. A comparable conventional building was selected for LCC comparison.

Table 5: Profile of Selected Cases

Description	Building 01 (C1)	Building 02 (C2)
Type of building	LEED certified building	Conventional building
Building category	Bank	Bank
Gross floor area (m2)	1,022	1,208
Construction period	3 Years	2 Years
Number of stories	2 Storey	3 Storey
Construction year	2009	2009
Completed year	2012	2011
Location	Western Province	Western Province

The cost details collected through document survey was analysed using Net Present Value (NPV). Through NPV analysis the LCC of GB and the conventional building was calculated. The analysis period was assumed as 50 years which is the average life time of an office building. A cross case analysis of NPV between green and conventional buildings was carried out. There are factors which influence the LCC of an office building. Therefore, the conventional building for the analysis was selected considering the factors affecting. There were identical features in both green and conventional building, i.e. location, type of business, gross floor area, and number of storey, year of construction and life time of building.

The construction cost, maintenance cost and operation cost details were collected from document study. The pattern of cost occurring was collected from the maintenance manager. Further, the rate of return excluding inflation for both the buildings was stated as 20%. In addition, maintenance manager said that the life time of GB is designed to 50 years. Therefore, in the analysis to compare the LCC, the life time of conventional building was considered as 50 years.

To calculate the amount to be saved today to cover the annual expenses is calculated from the following Eq. (01): i.e. Years purchase formula.

*YP = FV * [(1+r) n-1*(r (1+r) n)]* Eq. (01)

Where, YP= Present value of an annual amount receivable, FV= Annually occurring amount, r= Discount rate (Nominal rate) and n= Total years of cost occurring

The rate of return excluding the inflation was provided by the building. To carry out the LCC calculation the inflation rate should be considered because with the change of inflation rate the LCC might change. Therefore, the inflation rate was taken from the Central bank report. The average inflation rate from 2009 to 2017 was used to discount the present cost to the base year. The average inflation rate from 2009 to 2012/2011 was used to discount the construction cost to the base year 2009. The annual inflation changes over time therefore, to reduce the impact of inflation on LCC calculation, the average rate was used. The following Eq. (02) were used to calculate the nominal rate of return for the LCC calculation.

(1+ireal) = (1+inominal)/ (1+iinflation) Eq. (02)

Where, r_{real}= Rate of return excluding inflation, $r_{nominal}$= Rate of return including inflation and $r_{inflation}$= Inflation rate

A cross case analysis between green and conventional building was carried out to compare the NPV. All the costs were discounted back to year 2009 and standardized to cost per square meters. The GB cost impact compared to conventional building was calculated using Eq. (03).

Green Building Cost Impact = (PV of Green Building – PV of Conventional Building) / PV of Green Building Eq. (03)

Where, PV= Present Value

Table 6: Life Cycle Cost Analysis Comparison

Description	GB Cost/m^2	Conventional Building Cost/m^2	GB Cost Impact
Construction cost	115,864.64	109,687.79	5.33%
Maintenance cost	4,006.51	4,803.49	-19.89%
Operation cost	6,709.93	15,243.61	-127.18%
End life cost	(29.65)	(14.94)	49.61%
Life Cycle Cost	126,551.43	129,719.96	-2.50%

The outcome of this analysis is that the LEED certified office GBs shows 2.50% cost saving compared to conventional office building in Sri Lanka. Although the construction cost is high for GB there is a significant cost saving in maintenance and operation cost that is due to the incorporation of sustainable features in GB. Further, greater cost saving is experienced in the energy cost of GB i.e. electricity cost and water cost.

There are sensible variables in the LCCA in which the NPV is depended. In performing the LCCA certain assumptions were taken regarding i.e. inflation rate and the building life time. Sensitivity analysis was performed to examine how the variables could affect the NPV values. The sensitivity analysis was carried out for ±10% or ±20% of the actual inflation rate -4.941% to track the change in the GB LCC, when the inflation rate varies between ±10% to ±20%, the LCC of GB vary between 0.468% to 1.069%, which is an insignificant change that can be ignored.

Further, the sensitivity analysis carried out for ±10% or ±20% of inflation rate -4.699 to track the LCC change of conventional building. Accordingly, when the inflation rate varies between ±10% to ±20%, the LCC of conventional building vary between 0.733% to 1.656%, which is also an insignificant change that can be ignored. The sensitivity analysis was carried out for ±10% or ±20% of the life time of building which is 50 years to track the change in the GB LCC, when the life time of the building varies between ±10% to ±20%, the LCC of GB vary between 0.017% to 0.1%, which is an ignorable change that can be ignored.

Finally, the sensitivity analysis carried out for ±10% or ±20% of the life time of building which is 50 years to track the LCC change of conventional building. Accordingly, when the life time of the building varies between ±10% to ±20%, the LCC of conventional building vary between 0.014% to 0.466%, which is also an insignificant change that can be ignored. Therefore, conclusion can be made that with the change in the life time of the building there is an insignificant change in the LCC of conventional building. Further, this analysis also justifies that the cost saving from the office GB compared to office conventional building in Sri Lanka is 2.50%.

5. Conclusions and Recommendations

As the conclusion of this study, although the construction cost is 5.33% high for GB, 19.89% cost saving is experienced in maintenance cost and 127.18% cost saving is experienced from operation cost. Further, 49.61% income is experienced from end life cost. Finally, 2.50% cost is saved from GB throughout its life time.

GBs can be undertaken as a corporate social responsibility programme by the developers and the government can impose strict rules for building developers to incorporate sustainable features in their building and get green certification. LCC can be incorporated into the mandatory documents which are needed to acquire government approval for the project along with drawings and bill of quantities. GB council and green consultants need to do further research to implement GB with low running and initial cost in Sri Lanka.

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MANAGING CHALLENGES OF HIGH-RISE RESIDENTIAL BUILDINGS IN SRI LANKA: A FM FRAMEWORK

M.M.M. Rifas*, N.H.C. Manjula, D.M.P.P. Dissanayake and S.D.A. Soorige

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

High Rise Residential Building (HRRB) is a fast-growing trend in Sri Lanka. These are regulated and managed by the Management Corporation (MC). However, In Sri Lankan context MC is poor performance has led to various issues and challenges in HRRB. Hence, to better manage as well as overcome such issues and challenges by suitable professional concept in HRRB. Thus, the study was aimed to develop Facilities Management (FM) solutions to manage issues and challenges of the HRRB in Sri Lanka. To achieve the aim four objectives were formulated. As, to investigate the issues and challenges of managing the HRRB, current management practices, possible FM solutions to mitigate the identified issues and challenges and develop a framework to manage the HRRB in Sri Lanka. A qualitative research approach was followed to achieve the aim of the research wherein case study method was selected as the most appropriate research method. The required data were collected via semi structured interviews and analysed using cross case analysis. The findings of the study revealed issues and challenges in HRRB falls into three main categories, namely building management, finance and resident related issues. Subsequently, the issues and challenges faced by the MC of HRRB in Sri Lankan context, and FM solutions adapted to overcome such as issues and challenges were identified. Hence, a framework has been proposed in this study to successfully manage issues and challenges in HRRB in Sri Lanka. This research increases the present level of awareness and importance associated with effective management practices for HRRB management within the scope of FM. Further, it introduces a framework for well managed the HRRB.

Keywords:*Facilities Management; High Rise Residential Buildings; Management Corporation; Sri Lanka.*

1. INTRODUCTION

1.1. HIGH RISE RESIDENTIAL BUILDINGS

High-Rise Residential Buildings (HRRB) are also called “vertical cities”, having the potential to decongest urban sprawl (Kavilkar, 2014). These structures have developed into an economy generating industry, gaining worldwide popularity day by day. HRRB are parts of a multi-owner property that are owned by individuals, a property comprising land with a building or buildings of more than one unit of residential or non-residential accommodation (Anthonisz and Perry, 2015). HRRB facilities operate on a full-time basis, seven days a week and involve multiple individual user concerns and requirements, many of which are subjective (Wild et al., 2010). Consequently, there is a need to respond and adapt to almost constantly changing conditions. Each HRRB has its own unique features, challenges and opportunities.

The HRRB provide several significant and common features for residents that can be enjoyed by the residents, namely swimming pool, gymnasium, landscape, 24 hours security system, sports court and so on (Che-Ani et al., 2009). Thus, these features must be well maintained to ensure their functionality. The features are used in two different capacities, such as common area or shared spaces, and individual (end users) in high rise residential developments (Che-Ani et al., 2009). HRRB are vitally important when considering the sustainable design of cities and communities (Alyokhin et al., 2006). The HRRB standard is accountable for all management and maintenance aspects of the overseen properties and common facilities therein. Unfortunately,

*Corresponding Author: E-mail – rifasid@gmail.com

most of the HRRB schemes are not effectively managed by the existing Management Corporation (MC), leading to challenging issues during the course of their life cycle (Rashidah et al., 2016).

1.2. EVOLUTION OF HRRB PROFILE IN SRI LANKA

The concept of HRRB living dates back to the ancient roman empire, where citizens lived within the metropolis in the city centre in control of their own individual housing units but sharing common facilities with every other. This way of dwelling enabled a greater comfy and safe environment, which even nowadays, is the top cause of many humans to move into HRRB in Sri Lanka. Low rise residential building improvement has been in existence for more than 50 years in Sri Lanka (Kim, 2014). And the historical development of the Sri Lankan residential building industry is closely connected with the political changes that took place during the last five decades. In this respect, the significance economic adjustments may be categorized into pre and post economic liberalization period. The government channelled maximum investment into the building sector and was involved in the provision of low and middle income residential flats for the poor and the middle-income groups (Weddikkara & Devapriya, 2001).

Several past studies clearly accepted that the periods before 1977 were mostly unfavourable condition of property markets and the demand for the government HRRB reduced with time due to various reasons. The main reason was the bad maintenance of flats, for example garbage disposal, painting, services of common areas, lack of privacy (Hansen & Mladenović, 1997). In most of the instance the developer and the designer did not give much thought to post construction management aspects of these HRRB (Hansen & Mladenović, 1997).

1.3. CHALLENGES IN HRRB

The HRRB are facing unique challenges based on the functions of HRRB. The challenges of HRRB may be daunting and its outcome uncertain, but it must nevertheless be faced and dealt with (Hui, 2005). Studies have identified challenges under three area, namely building management, financial and resident-related (Che-Ani et al., 2009). Building management has been widely discussed in relation to HRRB (Wahab et al., 2016). It plays an integral role in the building operation. The building management of HRRB is very distinct due to the complicated arrangement for the MC (Ho & Liusman, 2016). The building management of the common areas of a building is a major challenge to its owners. There is a need for cooperation and coordination among them to maintain the shared facilities and common areas such as the entrance lobby, lifts, staircases, lighting system, drainage pipes, roof (Ho & Liusman, 2016). The building management also tends to get the least priority in the HRRB. Effective property management and facility maintenance is important in the economic aspects of high-rise living (Tiun, 2006). Building maintenance (Che-Ghani et al., 2016), energy management (Ali et al., 2010; Lecamwasam et al., 2012), service contract management (Hui & Tsang, 2004; Smith et al., 2004), waste management (Yeheyis et al., 2012), and property management (Noor et al., 2013; Yau, 2011) are the common challenges identified under building management of HRRB.

One of the primary challenges on HRRB is financial management (Adamu, 2012). Service charge and sinking funds are an amount of money accumulated by MC to fund the maintenance and improvement works in HRRB. Development and maintenance works are important to be performed to ensure that the building and its facilities are in good condition (Wahab et al., 2016).However, the lack of awareness in financial management makes it challenging to manage HRRB (Hassanain et al., 2013). The source in HRRB comes from the service charge and sinking fund collected from the residents. If these funds are insufficient, the efficiency of financial management will be affected and financial activities may not be done frequently and diligently (Wahab et al., 2016). Hence, challenges such as complexities of managing sinking fund (Tawil et al., 2012; Wild et al., 2010), utilities charge collection (Fanny et al., 2011; Ho and Gao, 2013; Mohd-Tawil et al., 2009), operation and maintenance budget administration (El-Haram & Horner, 2002), and handling procurements (Alexander, 2013) have been identified as financial challenges in managing HRRB.

In practice, most MCs under function because they do not have the expertise to run and maintain the HRRB residents' need (Irfan et al., 2008). If the MC fails to function nicely as stipulated in other regulatory bodies, the residents of the unique housing complex have the proper to summon the stated MC (Irfan et al., 2008). Most resident related challenges spring from this under function of MCs. Maintaining expected quality of life and safety (Belvisi et al., 2016; Al-Jokhadar and Jabi, 2017) and encouraging residents' active participation in

HRRB management (Housing, 2003; Wekerle et al., 1980) are the two most common challenges the MCs face in managing HRRB.

Now a day, the HRRB has faced to the Problem of resolve all customer complaints, proper way, as well as disputes among residents, environmental, social and psychological issues related with HRRB, difficult to managing outsource people for daily maintenance activities. Therefore, this study will be attempted to identify a simple and efficient framework to be implemented properly FM concept in HRRB. In HRRB, some studies have been carried out on managing of HRRB building. However, the gap highlighted the need of a proper framework to manage the challenges in HRRB based on FM practices in Sri Lanka.

1.4. ROLE OF FACILITIES MANAGEMENT IN HRRB

Facilities Management (FM) has extensive responsibilities for providing, maintaining and developing a number of services, which range from property strategy such as space management, building maintenance, administration and contract management including catering, cleaning and security in HRRB. FM at corporate level contributes to the delivery of strategic and operational objectives, while providing safe and efficient environment, which is necessary to the performance of the concerned business, on day to day level (Che-Ani *et al.*, 2009).As an increasing number of HRRB have been developed over recent decades, the demand for FM has also grown accordingly.

According to the Robathan (1996), FM services in HRRB have three levels.

- Lower level – the day to day support of operations such as maintenance, security, day to day communication services.
- Planned function- it includes space planning, building projects, building management system, resource, finance management, health and safety. At this level the facilities manager acts on strategic demand and develop tactical plans in line with the strategy.
- Board level – the director of the facilities that the HRRB, plant and services business need to be managed as assets that produce return on investments.

Myeda (2014) stated that the effective FM contributes to the delivery of operational objectives. On a day to day level, FM provides a safe and efficient working environment essential to the performance and business, whatever its size and scope. According to Ancarani and Capaldo (2005), the aforementioned obvious forms of FM services into two categories, as Hard FM and soft FM. Hard FM related to the management and maintenance of property, while the Soft FM includes to the management of support services, the build environment, including infrastructure facilities such as estate and property, indoor air, structure and fabric, water supply and electricity comes under the first category (Hard FM) and catering, cleaning, waste management, security system describes the latter category (Soft FM).

In HRRB practice, FM has been adopted differently, and in different contexts. The responsibility of FM in an HRRB management may differ from other contexts. In HRRB, this is typically conducted at all times of the day, every day of the year. The FM can be handled by an individual or a team, with services capable to be delivered by dedicated ‘in-house’ professionals or ‘out-sourced’ in whole or part to external providers (Hui & Tsang, 2004). An important role of the Facilities Manager is to provide services, meet varying expectations, support, and information, be a respectable listener, and deal with conflict to create a community environment residents are enthusiastic to call home (Irfan *et al.*, 2008). Their role includes dealing with several contractors and suppliers in carrying out maintenance and improvements, and providing services such as security, cleaning, and property maintenance (Noor *et al.*, 2013).

In HRRB, the Facilities Manager may be essential to manage staff and be part of the recruitment and induction process. Therefore, there are again required to have excellent people management skills (Irfan *et al.*, 2008). Their relationship with sustenance staff and contractors is critical in ensuring the building is a great place to live and work. FM services in the past were restricted to building operations only, however today the activities undertaken by Facilities Managers can extend throughout an entire HRRB life cycle.

Considering the involvement of FM in HRRB life cycle, it is apparent that the challenges of HRRB can be dealt with by ensuring sound FM practices incorporated to management of HRRB. Hence, this study aimed to develop FM solutions to manage challenges of HRRB in Sri Lanka.

2. RESEARCH METHODOLOGY

Considering the need of in-depth analysis of the nature of FM practice in HRRB, case study approach was selected to conduct this study. Three cases were selected from the Colombo metropolis, each having more than hundred dwelling units. Cases were examined mainly by conducting semi-structured and face-to-face interviews. The interviews were conducted with three key participants of the HRRB management team. Interviews were held with nine managerial level employees, each having more than five years of experience in the HRRB industry and Facilities Management. Table 1 briefs the case selection.

Table 1: Case Briefing

Case	A	B	C
Age of Building/Facility (Years)	7	4	8
Dwelling Units	300	475	200
Interviewee	Property Manager Maintenance Engineer Facilities Executive	Head of Condominium Property Manager Maintenance Engineer	Head of Condominium Property Manager Maintenance Engineer

Interviews were semi-structured as it allows in-depth and free flow of information from interviewees, whilst at the same time providing a framework/guide for conducting the interview. Data were collected under challenges of HRRB and possible solutions to those challenges. The collected data were analysed using content analysis. Cognitive mapping and NVivo software were used to perform the content analysis. Findings of the study are discussed in the subsequent section.

3. RESEARCH FINDINGS

3.1. CHALLENGES IN BUILDING MANAGEMENT

Building management has been identified as crucial in HRRB management by various researchers (Ho & Liusman, 2016; Smith *et al.,* 2004; Tiun, 2006; Yeheyis *et al.,* 2012). This includes maintaining the premises, managing energy consumption, handling service contracts and all housekeeping activities including waste management. Case study findings also suggested that, building management activities can often be challenging. According to the interviewees, when considering the building management of HRRB, the key objective is to protect the building property's value by ensuring a good and healthy condition of the building and facilities. In the case studies, it was revealed that most building management challenges occur due to poor maintenance of the facility. Also, according to the respondents, energy management issues, waste handling and difficulty in managing outsourced contracts led to several challenges in HRRB management.

3.2. FINANCIAL CHALLENGES

The financial activities are considered as non-core business activities, and managing these activities are often challenging. Financial challenges were one of the main types of challenges in HRRB management, as identified in the literature (Adamu, 2012; Hassanain *et al.*, 2013; Wahab *et al.*, 2016). This was asserted in the case studies as well. The interviewees pointed out that, in handling finances related to HRRB management, the situations like inadequate awareness, procedures, and funds make it challenging to smooth operation of the HRRB. According to all three cases, HRRB financial activities included preparing and monitoring the maintenance budgets, cost analysis, maintaining the procurement procedures, handling appropriate service charge collection and sinking fund management, and issues in managing these activities can lead to problematic situations.

3.3. RESIDENT RELATED CHALLENGES

According to the literature review, the issues brought up by resident behaviour of the HRRB can be difficult to manage since those need smooth and precise management in order to retain the tenant. Also, when building management and financial challenges are not managed properly, they also can lead to resident related challenges (Housing, 2003; Wekerle *et al*., 1980). The interviewees agreed that resident related challenges are the most sensitive and important issues in managing HRRB, since their core business is dependent upon the residents of the building. According to the findings of the case studies, residents are concerned about the quality of life, safety and security within the HRRB. Hence, whenever these aspects are of poor quality, it is challenging to retain the residents. Also, the interviewees pointed out that, in some instances, residents themselves behave in challenging manners that make the management of HRRB difficult.

Hence, the interviewees pointed out that careful planning is required to overcome these challenges. Also, they pointed out that the FM has a significant role to play in doing so. The next section looks in to the findings of the empirical study on FM role in HRRB.

3.4. FM SOLUTIONS TO OVERCOME HRRB CHALLENGES

According to the literature findings, FM scope in HRRB spans from day to day activities to strategic planning (Robathan, 1996). Only one case has employed a facilities executive out of the three cases, and in the other two, all FM work was handled by the maintenance manager with the help of their property managers. During the case studies, the interviewees agreed that, FM is mainly about taking care of the HRRB premises and creating the pleasant, cost effective, and safe environment for the tenants to live in. The interviewees pointed out that, commonly in a HRRB, the FM is expected to manage facilities operation and maintenance activities, and outsourced contracts. Also, the FM is held responsible for improving the quality of services provided for residents. Monitoring the financial management of the HRRB was another area FM was expected to be engaged in. Further, the FM needed to be able to develop and implement practices that support the overall performance of the building. As identified by the interviewees, the main competencies expected from a FM in a HRRB are;

- Operation and maintenance of plant and equipment
- Communication management
- Quality management
- Leadership and strategy in managing non-core activities
- Finance and business skills
- Fluency in environmental sustainability

In applying these competencies to solve the identified challenges of HRRB, FM has to undertake both day to day activities as well as strategic planning as per the interviewees. For instance, the property manager of case B pointed out that, a FM is expected to daily monitor the energy consumption of the building as well as to develop long term plans to reduce or conserve energy consumption of HRRB. Further, in Case A, the maintenance engineer argued that, in handling the residents' behaviours and complaints, with the human resources management skills, the FM is the best mediator to increase the awareness of residents regarding various challenges they themselves pose on HRRB management.

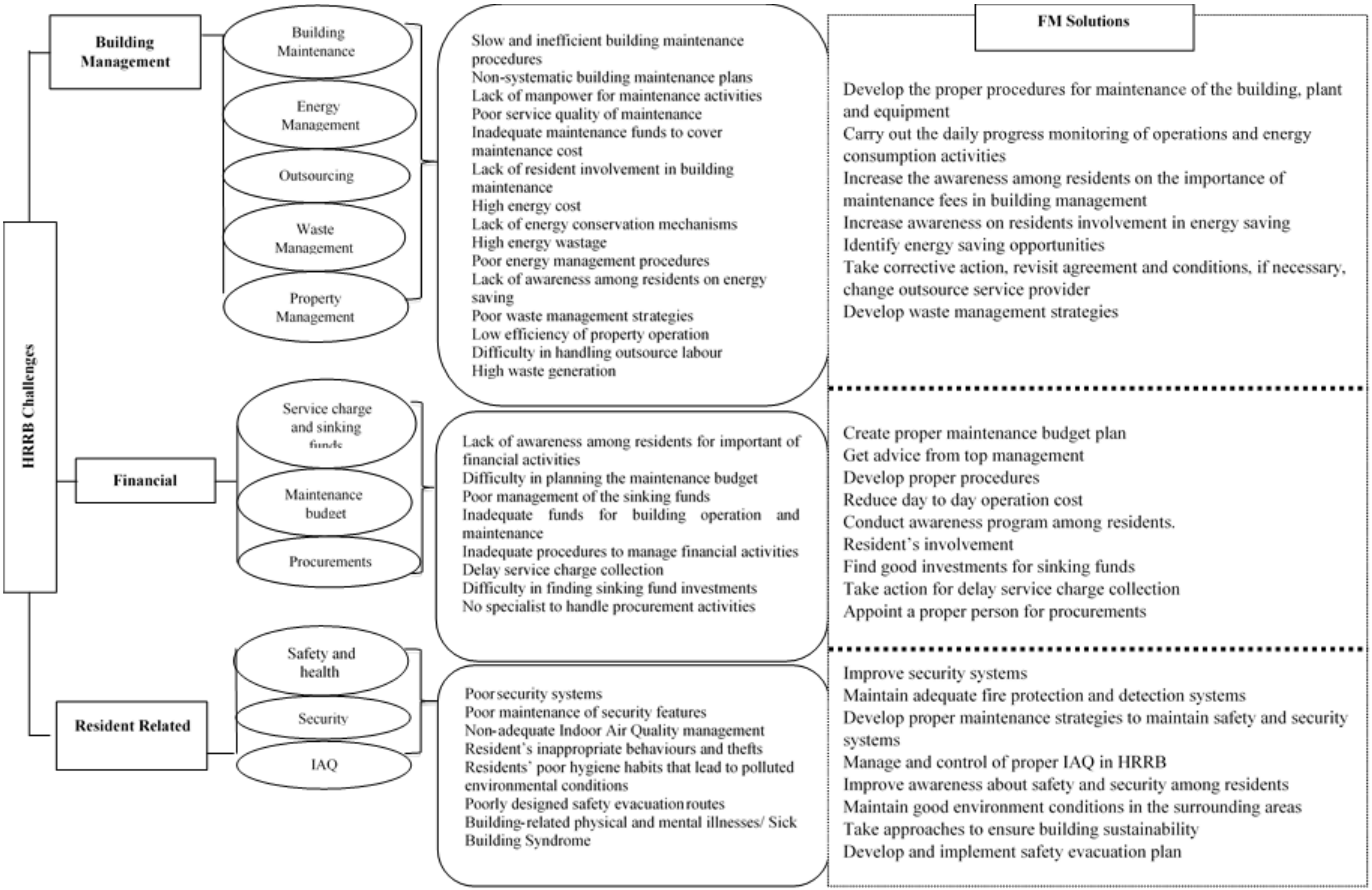

Figure 1: FM Framework to Manage HRRB Challenges

3.5. FM Framework to Manage Challenges of HRRB in Sri Lanka

Based on the literature and empirical findings, the challenges of HRRB were identified under three main categories as, building management, financial, and resident related. Further, the FM scope and practice were evaluated in relation to HRRB, leading to identify solutions to overcome the challenges in HRRB management. By incorporating these findings a framework was developed to assist the FM and related professionals in HRRB industry. This framework delivers the strategies which can be used to mitigate issues and challenges of HRRB management practices. Figure 1 denotes the developed framework.

4. Conclusions

With the rapid urbanisation and scarcity of land, HRRB industry has developed in to a fast growing and profitable industry. However, managing a HRRB is challenging as number of factors make the HRRB different from other types of buildings such as commercial or manufacturing buildings. For instance, the dwellings in HRRB are more than rent spaces when it comes to the residents. These dwellings provide the residents with homes, and different residents have different expectations from their homes. Hence, it is the duty of the management of HHRB to maintain acceptable quality standards and provide the residents with a good quality service. Thus, employing a FM in HRRB emerged as a good solution to overcome most of the challenges as FM is about integrating people, process and technology to provide the customer with the best experience within the company.

A literature review was first undertaken to identify the challenges in managing HRRB, as well as the FM scope and practices in HRRB. A case study was then undertaken to identify the scenario in Sri Lanka, related to the study. The study identified various challenges that may occur in managing HRRB under three main areas, namely, building management, financial, and resident related. These challenges were interrelated and concurrent depending on the management, as well as the residents. Further, the involvement of FM and possible FM solutions to the challenges were also identified. These were used to develop a FM framework that could assist the FM professionals and HRRB management to effectively manage HRRB challenges and provide the residents with quality living spaces, while benefiting the organisation as well.

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MINIMISING CONCRETE WASTAGE IN SRI LANKA USING LEAN CONSTRUCTION TECHNIQUES

P. Coomasaru[1*], S.D.T.S. Wickramasuriya[1] and B.A.K.S. Perera[2]

[1]Department of Quantity Surveying, SLIIT, Sri Lanka

[2]Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Concrete is a major component of construction waste. The amount of concrete wasted in Sri Lanka is significant compared to the amounts wasted in other countries. Traditional strategies adapted to minimise concrete wastage have not been successful. Although lean construction can eliminate waste, there is very little research that has been done on this subject. The aim of the study was therefore to identify the suitability of lean techniques in minimising concrete waste generated during pre and post contract stages of construction in Sri Lanka. Qualitative research methods were used to achieve this aim. A literature review and a set of structured interviews with fifteen experts working in the construction industry were used to collect the required data. The data collected were analysed using content analysis. Total quality management, just in time, process re-engineering, value-based management and total productive management were identified as the lean techniques that can be used to minimise the waste of concrete in the construction industry in Sri Lanka during pre and post contract stages of construction.

Keywords: *Building Construction Projects; Concrete Wastage; Lean construction; Pre and Post Contract Stages.*

1. INTRODUCTION

Lean construction is a philosophy invented in Japan subsequent to the discovery of lean manufacturing in late 1950s. The main objective of lean construction is to provide more value to customers by using fewer resources so that the amount of waste generated is minimized (Alves *et al., 2012*). Serpell and Alarcon (1998) have revealed that construction process can be improved by reducing or eliminating altogether its non-value added activities through the adoption of lean construction principles. Howell (1999) also has considered lean construction which is focussed on the delivery process of a product, improving the performance of the product to meet customer needs, product and process design, and the maintenance of the product from its planning to delivery as a concept that can be utilized to reduce non-value added activities of construction.

Waste which is generated by activities that lead to material losses and unnecessary work incurs additional costs without bringing in any profits (Agyekum *et al.,* 2013). Therefore, the minimization of material wastage will not only improve project performance but will also positively contribute to the economy of the country.

Nellickal *et al.* (2015) have mentioned that a construction project should be considered as a "project-as-production system". Kazaz *et al*. (2015) have identified that around 10% of the budget of a construction project is assigned for concrete works. Waste of concrete is one of the major contributors to the generation of construction waste in the world (Nagapan *et al.*, *2012*). Chu (2004) discovered that incremental contribution made by waste of concrete to the total cost of a project can be as high as 4%. One of the critical negative results of wastage on a construction site is unwanted cost over-runs (John & Itodo, 2013).

The amount of concrete wasted in the construction industry in Sri Lanka is significant when compared to what is wasted in other countries (Kulatunga *et al.*, 2005). It has also been revealed that because of the excessive

*Corresponding Author: E-mail - p.cooma@gmail.com / pramuditha.c@sliit.lk

use of concrete and mortar in Sri Lanka without properly managing those, the percentage wastage of these two materials in the country are as high as 21% and 25% respectively. Therefore, a research on minimizing concrete waste in Sri Lanka will be important in today's context.

1.1. RESEARCH PROBLEM

According to Garrido and Pasquire (2011), Kalathunga et al. (2006), Ekanayake and Sandanayake (2017), Ballard et al. (2003) and Amarathunga et al. (2006), construction wastage has been the subject of several research studies done in Sri Lanka. However, most of these past research studies have been on the wastage of materials and minimization of that wastage (Silva & Vithana, 2008). Actions taken to minimize concrete waste using traditional methods have so far been unsuccessful and thus there is a need in the construction industry for a well-established mechanism that will minimize waste of concrete (Kulatunga et al., 2006). Researchers have already found that lean principles can successfully minimize waste in the manufacturing industry (G.L.D. Wickramasinghe & Wickramasinghe, 2017). Even though several research studies have already been carried out on the use of lean techniques in the construction industry, very little research has been done on minimizing concrete waste using lean principles. Thus, it is apparent that there is a research gap and that there is an emerging need and a demand in the construction industry for the further investigation of lean principles. Therefore, this research was aimed at identifying lean construction methods that will minimize wastage of concrete in the construction industry in Sri Lanka. The objectives of the research study were to identify lean principles and techniques and their applicability to Sri Lanka, concrete wastage at different stages of a project and lean techniques that are suitable to minimize concrete wastage.

2. LITERATURE REVIEW

2.1. CONSTRUCTION WASTE

According to Bodkhe and Waghamare (2016), construction taking place in a country will significantly contribute to the country's economy. Thus, if construction waste could be minimized, it will impact not only on the client and the contractor but also on the country's economy. E. Skoyles and Skoyles (1987) have stated that if a project is to be profitable, it will be important to understand how waste could be reduced and that for a project to be successful the waste margin will have to be acceptable. Construction waste is usually generated throughout the construction of buildings, their remodelling, refurbishment and renovation (Nitivattananon & Borongan, 2007). This waste can be categorized as solid, liquid or other substances. According to Patil et al. (2013), construction waste indicates the loss of materials and unnecessary work which adds extra cost to a project without adding any value to the product and this waste can be measured in terms of costs including opportunity costs. John and Itodo (2013) have stated that the contribution made by construction material wastage to the cost overrun of a project is between 21% and 30%. Agyekum et al. (2013) have revealed that the construction industry in USA had generated 170 million tons of waste in 2003. Chu (2004) discovered that material waste such as concrete, block work and those arising from screening, plastering and packaging contribute 4%, 10%, 15 % and 5% respectively to the total cost of a project.

According to Kazaz et al. (2015), concrete wastage is the most important type of wastage in the construction industry. Their study has revealed that concrete waste by weight accounts for approximately 50-55% of the waste that is generated during construction. There are several types of waste that can be identified such as poor workmanship and losses that occur when transporting materials to construction sites and those that occur during placing activities. What is most critical among the different types of concrete waste is the quantity of excess material found in them (V. Tam & Tam, 2007). Marco and Rabinder (1998) have stated that a significant quantity of ready-mixed concrete gets disposed due to reasons such as high slump losses caused during transportation or because the quantity that has been ordered is more than what is required.

2.2. CONSTRUCTION WASTE IN SRI LANKA

Sri Lanka is a developing country where construction is taking place all over the country. According to Kulatunga *et al*. (2005), cost of construction wastage has a significant impact on the construction industry in the country. Furthermore, according to them, the main reasons for the material wastage in the construction industry are the design changes made during construction, lack of dimensional coordination of projects and poor workmanship. They have also revealed that the percentage wastage of concrete and mortar in the country are 21% and 25% respectively which are a result of their excessive usage without careful handling. Kulatunga *et al*. (2006) have found that the percentage wastage of sand, lime, cement, bricks, ceramic tiles, timber, rubble, steel, cement blocks, paint and asbestos sheets in Sri Lanka are 25%, 20%, 14%, 14%, 10%, 10%, 7%, 7%, 7%, 5% and 3% respectively. Kumara (2009) identified six main reasons for the material wastage in the construction industry in Sri Lanka, namely design errors and design changes made during construction, procurement system errors, improper material handling, operational errors, and bad weather conditions.

One of the commonly used methods for dividing construction process into stages is the Royal Institute of British Architects (RIBA) Plan of Work. According to RIBA Plan of Work (2007), the simplest and the most common classification of the construction stages are preparation, design, pre-construction, construction and use which were considered in this research as well. Past research have identified different stages of construction during which concrete wastage can take place.

2.3. History of Lean Concept and Lean Construction

A considerable number of technologies and management changes were introduced to the manufacturing industry after the Second World War (Womack & Jones, 1996). There are fourteen principles which formed the basis on which quality and efficiency of Toyota productions were to be increased. Those principles which have been divided into four groups are applicable to other industries as well (Liker & Meier, 2006). Lean production is one concept introduced by Taiichi Ohno in the 1950s to minimize wastage in Toyota productions (Howell, 1999).

Womack and Jones (1996) have found sharing experience with others and re-use of knowledge to be the best ways to learn lean principles. Ballard and Howell (1998) have stated that the term "value" can be called as the most appropriate formation of a product or service provided to the customer at the right time at a reasonable price while adhering to correct quality standards. The main idea underlying the lean concept is producing more value for customers using fewer resources (Hines *et al*., 2004 and Glenn *et al., 2003*). Construction activities can be divided into two groups: conversion activities and flow activities (Koskela, 1993). Conversion activities add value to the product while flow activities do not add any value. Flow activities deal with activities such as waiting and inspection. Maximizing of the performance and the delivery process has been identified as a significant feature of lean construction.

Womack *et al*. (1991) have stated that compared to mass production, lean construction uses fewer resources in terms of man hours spent in the factory, manufacturing space, investment in tools and engineering hours spent on developing the product. Aziz and Hafez (2013) have stated that the productivity in the construction industry has been on the decline all over the world for almost 40 years now. One way to overcome this situation is to implement lean construction in the construction industry as well.

2.4. Lean Construction Principles / Techniques

The most important lean construction principles / techniques are Just In Time (JIT), Total Quality Management (TQM), Time Based Competition, Concurrent Engineering (CE), Process Redesign (or Reengineering), Value Based Management (VBM), Visual Management (VM), Total Productive Maintenance (TPM) and Employee Involvement (EI).

The technique, Just in time, which was developed and applied by engineers who worked in the Toyota manufacturing plant in the 1950's eliminates or reduces non-value added activities (inventory) (Salem *et al.*, 2006).

Total quality management, a technique that refers to the continuous improvement of the production of goods and services, is basically divided into three areas: expanding quality control from the production department to all departments, expanding quality control from workers to management, and expanding the concept of quality to cover all operations. (Koskela, 1992).

Time based competition is a technique that shortens lead time and provides benefits such as the decrease or the elimination of the works that are not related to the production process, decrease of the inventory and easy identification of problems.

Concurrent engineering deals basically with the design phase of a product (Rouibah & Caskey, 2003). It is similar to just in time and total quality management although it has not originated from either of them.

Process redesign or re-engineering refers to the primary re-configuration of tasks and processes of a project (Reijers & Mansar, 2005). Re-engineering breaks down tasks into several smaller tasks using fundamental assumptions so that they can be designed for maximum effectiveness.

Value based management is a principle (VBM) that focuses on maximizing the value of a product at its conceptual stage itself to make it competitive. Firms that use value based management strategies are focussed more on the interests of customers. One of the main characteristics of value based management is the continuous improvements made to increase the benefits provided to the customers (Christopher & David, 2001).

Visual management is focussed on visual control, standardization and workplace organization (Bell & Davison, 2013). The main objective of visual management is to establish standards that can be understood easily by all employees.

Total productive maintenance gets multi skilled workers to independently handle the maintenance of equipment. It mainly focuses on maximizing production by maintaining the operating system at its best condition (McKone *et al.*, 2001).

Employee involvement empowers workers to take decisions on their own on matters affecting their work. Here, in order to avoid waste, multi skilled workers or teams of self-directed operators take responsibility for customers or product driven production (Wilkinson *et al*., 1992).

All these lean principles and techniques are used in construction projects to minimize waste (Salem *et al*., 2006; Koskela, 1992; Rouibah & Caskey, 2003; Reijers & Mansar, 2005; Christopher & David, 2001; Bell & Davison, 2013; McKone *et al*., 2001; and Wilkinson *et al.*, 1992)

2.5. APPLICABILITY OF LEAN CONSTRUCTION TO MINIMIZE CONCRETE WASTE

Nowotarski *et al.* (2016) have stated that in the construction process, 57% of the resources are wasted and that a considerable portion of this waste is concrete. They have further mentioned that JIT is being applied in more and more companies and that the implementation of the 5S method reduces wastages. According to Rybkowski (2013), lean techniques reduce concrete waste and provide more benefits.

According to Madushan *et al*. (2016), since Sri Lanka is still a developing country, its construction industry is yet to become familiar with lean construction. They have further identified the absence of programs to educate professionals about lean principles and the absence of discussions on the benefits of lean principles as the factors that make it difficult to implement lean concepts in the country. Senaratne and Wijesiri (2008) have discussed the applicability of lean construction to Sri Lanka and their findings reveal that lean construction is acceptable to the construction industry of the country. They have recommended that lean concepts be implemented within the construction industry and have verified the feasibility of their application by making available these concepts to several companies. Therefore, it is worth studying the use of lean techniques in the Sri Lankan construction industry.

3. RESEARCH METHODOLOGY

There are three different approaches for research: quantitative, qualitative and mixed approaches (Creswell, 2007) and in any research the approach that is most appropriate to the research requirements has to be selected (Dawson, 2002). Willis (2007) recommends proceeding with qualitative information when an in-depth analysis is required.

Most professionals in the construction industry in Sri Lanka do not understand the use of lean techniques and only a few have theoretical and practical knowledge of the subject. Therefore, data could be collected from only fifteen experts all of whom had more than fifteen years of experience in the construction industry and more than five years of experience/ knowledge in lean practices.

In order to cover the research objectives, the expert interviews had to be based on guidelines that focused on three broad areas: identification of the applicability of lean principles to Sri Lanka, identification of the types of concrete wastage and the identification of lean principles suitable to minimize concrete wastage during each stage of construction. "NVivo 11" content analysis software was used to analyse the findings.

4. ANALYSIS AND RESEARCH FINDINGS

The main objective of the expert interviews was to ascertain the relevance of the findings of the literature review to construction projects in Sri Lanka. Table 1 presents the profiles of the experts who took part in the expert interviews.

Table 1: Details of the Expert Interviewees

Code	Organization	Designation	Profession	Experience in years
I1	Consultant	Director	Chartered Quantity Surveyor	> 25
I2	Contractor	Contracts Manager	Chartered Quantity Surveyor	> 25
I3	Contractor	Contracts Manager	Chartered Quantity Surveyor	21-25
I4	Contractor	Managing Director	Chartered Engineer	> 25
I5	Contractor	Senior Project Manager	Chartered Engineer	> 25
I6	Contractor	Project Manager	Chartered Engineer	> 25
I7	Contractor	Managing Director	Chartered Engineer	21-25
I8	Contractor	Chief Quantity Surveyor	Quantity Surveyor	21-25
I9	Consultant	Chief Quantity Surveyor	Quantity Surveyor	21-25
I10	Consultant	Chief Quantity Surveyor	Quantity Surveyor	16-20
I11	Consultant	Chief Quantity Surveyor	Quantity Surveyor	16-20
I12	Consultant	Quality Assurance /Quality Control Manager	Civil Engineer	21-25
I13	Contractor	Civil Engineer	Civil Engineer	16-20
I14	Contractor	Civil Engineer	Civil Engineer	16-20
I15	Contractor	Civil Engineer	Civil Engineer	16-20

4.1. *IDENTIFICATION OF LEAN PRINCIPLES, TECHNIQUES AND THEIR APPLICABILITY TO SRI LANKA*

Nine lean principles identified from the literature and expert interviews were subsequently used to identify their applicability to Sri Lanka. Table 2 presents the results of the interviews.

Table 2: Identification of Lean Principles and their Applicability to Sri Lanka

Lean principle	Applicability of lean principles														
	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15
JIT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
TQM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
TB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CE	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
VBM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
VM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	✓	✓
TPM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
EI	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
OSHAS	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×
CIC	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×

All interviewees agreed that JIT, TQM, TB, PR, VBM, TPM and EI can be applied to reduce waste in all stages of construction projects in Sri Lanka. For example, JIT can be applied to reinforcements as the required amount of reinforcements can be ordered and stored at the construction site during the first stage itself. JIT is important in the case of concrete as it has to be transported to the site at the required time to prevent it from getting rejected due to delays.

Two of the interviewees considered CE and VM as being not suitable to every stage of construction since according to them the dynamic nature of the projects will not permit their practical implementation in Sri Lanka.

Two new lean principles, Occupational Health and Safety Assessment Series (OSHAS) and Continuous Improvement Circle (CIC), were identified by one interviewee (I2) who was confident of their benefits because of his experience in the industry.

Interviewees stated that there are barriers to applying the identified lean principles to the Sri Lankan construction industry. According to them, the introduction of new technologies in Sri Lanka is always a challenging exercise as there is hesitancy on the part of the industry to adapt and adjust, the country being still a developing country. Moreover, employees are so much familiar with the existing systems that they tend to resist change. According to the experts, absence of proper guidance to apply these lean principles to the construction industry is a barrier to implementing lean principles in the country. They opined that it is often found that new concepts and technologies are difficult to implement as they incur additional costs thereby becoming a barrier to applying lean principles in Sri Lanka. They were also of the view that professionals are often too busy to study and experiment with new philosophies. However, they considered that lean construction being a management strategy, lean principles should be applicable to the construction industry of any country as they will improve productivity and efficiency of material usage, reduce the idling time of machinery and get optimum service and higher productivity from the labourers.

The interviewees further mentioned that adopting lean techniques may create logistic problems such as the difficulties encountered during transportation, difficulties caused by government agencies, scarcity of resources, lack of knowledge of managing lean principles and reluctance on the part of management to adopt lean techniques.

4.2. IDENTIFICATION OF CONCRETE WASTAGE DURING DIFFERENT STAGES OF CONSTRUCTION

The main stages of a construction project, causes of concrete wastage during each stage and the lean techniques that can be applied to each stage that were revealed from the findings of the literature review and the interviews are presented in Table 3. From the literature review, three stages of construction projects, design stage, pre-construction stage and construction stage, were identified in accordance with the RIBA Plan of Work (2007). All the interviewees confirmed that the stages in local projects are same as the stages identified from the literature review.

4.2.1. IDENTIFICATION OF CONCRETE WASTE GENERATED IN DIFFERENT CONSTRUCTION STAGES

Most of the interviewees stated that all types of waste are generated during the design stage. Communication errors were identified to be the most critical cause of concrete waste occurring during this stage. Selection of incorrect admixtures and incorrect design mixes was also identified as generating waste during this stage (Table 3).

From the literature review, poor workmanship and selection of unsuitable transportation methods were identified as the two causes of concrete waste generated during the pre-construction stage. All of the interviewees agreed that poor pre planning is the cause of most of the waste generated. Furthermore, selection of incorrect admixtures also was identified as generating concrete waste (Table 3).

All the interviewees identified the same types of wastage for the construction stage. They further stated that rejection due to delay in transportation is one type of wastage that often occurs during construction. The other types of wastes that were identified were excess concrete orders, incorrect placing methods, and negligence of workers or labourers (Table 3).

4.2.2. IDENTIFICATION OF THE LEAN TECHNIQUE MOST APPLICABLE TO EACH CONSTRUCTION STAGE

Total quality management, process re-design or re-engineering and total productive maintenance were identified by all the interviewees as techniques applicable to the design stage. Six of the interviewees were of the view that value based management can also be used during this stage (Table 3).

Table 3: Applicability of Lean Techniques to Each Construction Stage

Types of concrete wastage identified from the literature / interviews		**Construction stage**	**Lean principles/techniques that can be applied to minimize concrete wastage based on the interviews**															
Literature	Interviews		Lean Principle / Technique	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15
Poor workmanship	Poor workmanship Incorrect mix design Incorrect admixtures Communication errors Poor pre-planning	Design stage	TQM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			PR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			TPM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			VBM	×	✓	×	×	×	✓	✓	×	✓	×	✓	✓	✓	×	✓
			JIT	×	✓	×	×	✓	✓	×	×	×	×	✓	×	✓	×	✓
			TB	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
			CE	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
			VM	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
			EI	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Poor workmanship	Poor workmanship Overdose or under dose of admixtures Unsuitable ready mix plant Negligence Unsuitable transportation methods	Pre-construction stage	TQM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			VBM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			JIT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×
			TB	✓	×	✓	✓	✓	×	×	✓	×	✓	×	✓	✓	×	✓
			TPM	✓	✓	×	×	✓	×	✓	✓	×	×	✓	✓	✓	×	✓
			EI	✓	×	×	✓	✓	×	✓	×	✓	×	✓	✓	✓	×	✓
			PR	✓	×	✓	×	✓	×	×	×	✓	✓	×	×	✓	×	✓
			VM	✓	×	×	×	✓	×	×	×	×	✓	×	×	✓	×	✓
			CE	×	×	×	×	✓	×	×	×	×	×	×	✓	✓	×	✓
Poor workmanship Excess material order Placing methods Losses during transport	Poor workmanship Excess material orders Incorrect placing methods, Losses during transport Re-work and rejections Poor quality of concrete Defective transportation methods Rejection due to delay in transportation, Wastage during placing Curing failures & machine waste Incorrect levels, Insufficient formwork Reinforcement failures	Construction stage	TQM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			PR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			TB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			VM	✓	✓	✓	×	×	✓	×	✓	✓	✓	✓	✓	✓	×	✓
			EI	✓	×	×	×	✓	×	✓	✓	✓	×	✓	✓	✓	×	✓
			JIT	×	✓	✓	×	×	×	✓	✓	×	×	✓	×	✓	×	✓
			TPM	✓	✓	×	×	✓	×	×	✓	✓	✓	×	×	✓	×	×
			CE	×	×	×	×	✓	×	×	×	×	✓	✓	×	✓	×	✓
			VBM	×	✓	×	×	×	×	×	×	×	×	×	×	✓	×	×

All interviewees agreed that just in time, total quality management, and value based management can be applied in pre-construction stage. Time based competition; total productive maintenance; and employee involvement were also identified by more than six interviewees as lean techniques applicable in this stage (Table 3).

Total quality management, time based competition and process re-design or re-engineering were identified by all the interviewees as being the lean principles applicable in the construction stage while more than 6 interviewees considered visual management, total productive maintenance and employee involvement as being also applicable in this stage (Table 3).

4.3. USE OF LEAN PRINCIPLES IN CONSTRUCTION PROJECTS

By reviewing literature, nine lean principles were identified as being suitable for use in construction projects. Two additional principles were identified by one interviewee (Table 2).

The interviews were used to validate the applicability of the lean principles identified through the literature review, to Sri Lanka (Table 3). Eight of the twelve interviewees agreed that all nine principles are applicable to the Sri Lankan construction industry while four did not agree with the applicability of one or two principles.

Construction stages that could contribute to concrete waste were identified from both the literature review and the interviews. All the interviewees agreed with them based on their experience (Table 3). The construction stages that were identified from both the literature and interviews as being suitable for consideration in reducing concrete waste are design, pre-construction and construction stages.

From the literature review, one type of concrete waste was identified to occur in the design stage while the other types occurring in this stage were identified from the interviews. The interviewees agreed with all types of concrete wastage identified through the literature review. They wanted to include three additional types of waste for the design stage (Table 3): incorrect mix design, incorrect admixtures and communication errors.

For the pre-construction stage, only a few types of concrete waste were identified from the literature review and all the interviewees were in agreement with them. The interviewees wanted several other types of waste also to be included for this stage (Table 3).

For the construction stage, three types of concrete wastage were identified from the literature review and the expert interviews. The experts identified eleven types of wastage additionally for this stage (Table 3). Findings reveal that the construction stage can generate more concrete waste than other stages.

The interviewees also identified the lean principles that are suitable to minimize wastage at each stage of construction. Just in time and value-based management, according to them, are the most suitable lean principles that can minimize concrete wastage at the stage of preparation (Table 3). Total quality management, process re-design or re-engineering and total productive maintenance are the lean principles most suitable to minimize concrete wastage during the design stage of construction as per the findings (Table 3). Just in time, total quality management, and value-based management are identified to be the lean principles most suitable to minimize concrete waste during the pre-construction stage (Table 3).

It is also revealed that total quality management, time based competition and process re-design or re-engineering are the lean principles most suitable to minimize concrete wastage during the construction stage (Table 3).

Total quality management principle was identified to be the most suitable method for minimizing concrete wastage during all three stages of construction. Therefore, on the whole, total quality management can be considered as the most suitable and most applicable technique that will minimize concrete wastage.

5. CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

5.1. CONCLUSIONS

The aim of this research was achieved by identifying the lean principles that can minimize concrete wastage in Sri Lanka. Poor workmanship, incorrect mix design, poor pre-planning, communication errors, and negligence were identified as causing concrete wastage in all stages. Total quality management was found to be the lean technique most suitable for minimizing concrete wastage during all three stages of construction (Table 3).

The research findings indicate that there is an imperative need to implement lean construction in the Sri Lankan construction industry because of the large amount of concrete waste generated daily. Sri Lanka being a developing country, only few professionals working in the construction industry in the country are knowledgeable about lean construction. Although several companies have already implemented lean construction, most companies are yet to implement it.

5.2. *RECOMMENDATIONS*

This study covered several aspects related to minimization of concrete wastage using lean construction techniques. Therefore, the following recommendations will assist in implementing lean principles in the Sri Lankan construction industry and minimize concrete wastage.

1. Educating professionals and all others engaged in the construction industry about lean construction.
2. Implementing lean construction with regard to wastage of other types of material such as cement and reinforcements.
3. Encouraging cooperation between contractors and clients in applying lean concepts to minimize wastage.
4. Changing the negative attitudes towards the implementation of new systems

5.3. *LIMITATIONS*

The dearth of professionals knowledgeable in lean construction was the main concern during the study. Only few professionals were aware of this new philosophy while others were totally ignorant of it. Therefore, only fifteen experts could be interviewed during the study which can be considered as a limitation of the study.

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MODEL FOR ANALYSING THE DRIVERS AND BARRIERS OF E-PROCUREMENT ADOPTION TO ENHANCE THE PERFORMANCE OF PROCUREMENT SYSTEM IN SRI LANKA

A.F. Fayasa*, Lalith De Silva and D.M.P.P. Dissanayake

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

The growing need and competitive nature of firms in the modern world have been directed the organisations in discovering new solution to improve their business value and performance. E-procurement (EP) system is realised as an innovative technique by most of the practitioners and rate of adaptation is intensely increasing around the world. However, key literature findings revealed that organisations are struggling with EP system due to the lack of knowledge on factors influencing the successful implementation. This situation is similar to the Sri Lankan context as well. In this context, it has become a timely requirement to develop a mechanism for analysing such factors to facilitate a successful implementation. Therefore, this study attempts to develop a model for analysing the drivers and barriers of EP adoption to enhance the performance of procurement system in Sri Lanka. A qualitative approach was followed in which multiple case study was selected as an appropriate method for the research which allows to analyse within each setting and the evidence created from this type of study is considered robust and reliable. Accordingly, semi-structured interviews were conducted among the selected three respondents from each case to collect the data. Captured data was structured and analysed by using manual content analysis method with the support of NVivo software. Empirical investigation validated twenty-four drivers and seventeen barriers which are influencing the successful EP adoption. The research findings further disclosed six strategies to strengthen the drivers and weaken the barriers of EP adoption. Finally, a model was developed based on the research findings in order to facilitate the adoption of EP system in Sri Lankan context.

Keywords:*Barriers; Drivers; Electronic Procurement (EP) System; Strategies.*

1. INTRODUCTION

In the recent years, the internet has had revolutionary effects on corporate purchasing practices, in both direct and indirect purchases (Puschmann and Alt, 2005). They further specified that diffusion of new e-business technologies in the late 1990s has created new working practices and new business models for corporate business functions. According to Brown (2005), business models and expectations of people for the quality and efficiency of information system and service delivery has dramatically changed by the practice of innovation in Information Communication Technologies - ICT (Brown, 2005). Well defined ICT facilitates the application of alliances which are used by an organisation for the integration of Information Technology (IT) infrastructure and supply chain activities are known as EP system.

Though EP brings vast benefits to the organisations, number of complications are failing the successful adoption of EP system. Unless having the knowledge on influencing factors, it is difficult to adopt the EP system by any organisation. In this context, it is clear that there is a need of understanding the factors influencing EP adoption. Therefore, this study intended to develop a model for analysing the drivers and barriers of EP adoption to direct the industrial practitioners to move towards EP system by knowing the concept.

*Corresponding Author: E-mail - aariffaya@gmail.com

The research paper commenced with the comprehensive literature review which focused on theoretical status of EP and drivers and barriers of EP system. The next section presents the method of study followed by findings and analysis of study. Finally, this paper presents conclusions and recommendation provided in the research study.

2. INTRODUCTION TO E-PROCUREMENT

E-procurement (EP) is one of the key tool to electronically acquire goods and or services which is still novel concept to many organisations nevertheless it is diffused around the world as the result of many businesses are starting to realise the importance of its adoption (Shale, 2014). According to the study by Subramani (2004), an enormous opportunity for companies has been created using e-business to reinforce their procurement processes and opened new efficient means of managing business functions which allows to make the pertinent procurement decisions of engineering items, goods and or services (Shale, 2014).

There is no any standard definition founded for EP system (Gunasekaran and Ngai, 2008). Researchers and practitioners have been using the concept based on the context where they applied it. Accordingly, working definition is developed for this study by referring previous studies, which is;

> *"a process of using internet-based platform to acquire goods and services in terms of need identification, supplier selection, communication, price negotiation, ordering and evaluation of customer satisfaction in order to maximize the organisational efficiency and minimise the operational cost of acquisition".*

EP just not only the mean of online purchasing but also it connects the wide range of suppliers and buying organisations within the procurement network which take up the EP programs that would be combined purchasing process across the multi-functional departments without eliminating individual control and allow to obtain a product or service at the best quality and price from multiple suppliers in the e-market (Shale, 2014). It helps to enhance the efficiency of an organisation and enables overall process of procurement system to become simple and faster (Chau, 2006).

2.1. *APPLICATIONS OF E-PROCUREMENT SYSTEM*

EP is simply aspects of the procurement function which support by various forms of electronic communication system (Knudsen, 2002). It is not only single application, but it comprises of various tools were addressed and described by de Boer, Harink, and Heijboer (2001). The study by Harink (2003) specified that there are six form of EP system including e-sourcing, e-tendering, e-reverse auctioning, e-contracting, e-ordering and web-based Enterprise Resource Planning (ERP). Following applications of EP system have been adapted based on the study by Harink (2003) and those tools are placed on the procurement process as shown in Figure 1.

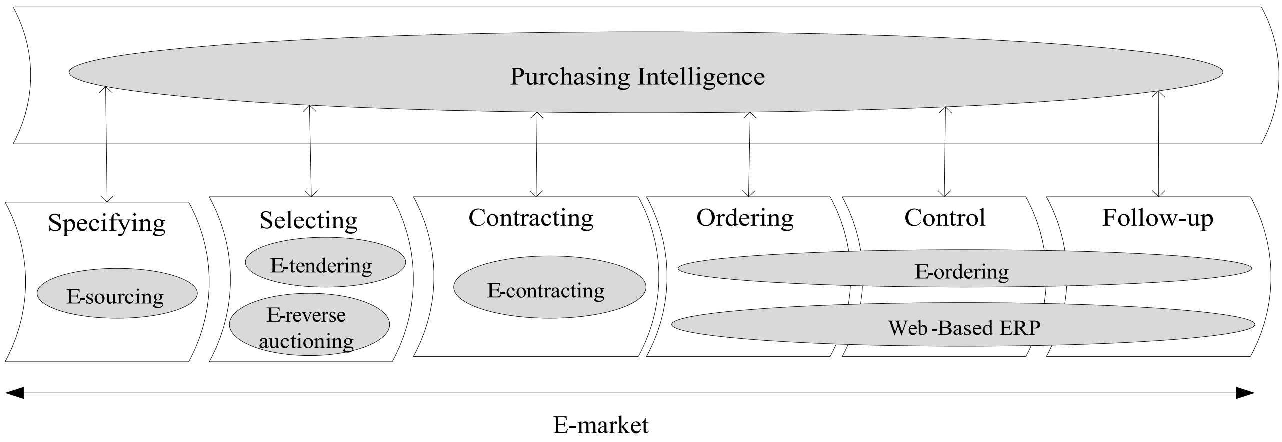

Figure 1: Applications of EP system

Source: Adapted from Harink (2003)

Above figure shows the way of EP applications flow through the procurement process. This process usually involves sub-processes such as specifying, selecting, contracting, ordering, control and follow-up. In general, procurement processes are varying between organisation to organisation based on the process time and supplier relationship (Trkman and McCormack, 2010). However, basic process of procurement is start from the forecast planning and coordination of procurement to end with settlement of outstanding balances.

2.2. DRIVERS OF E-PROCUREMENT ADOPTION

According to the Eadie *et al*. (2007), drivers for the adoption of EP system have been identified by number of authors. The primary enabler of adopting EP technology is reduction in overall cost and efficiencies. According to the argument of Gonzalez *et al*. (2004), use of EP solutions have been positively affect the performance and practice of procurement system in an organisation which leads to facilitates the continuous improvement in procurement process and performance. As well as adopting e-solutions will absolutely contribute to the improvements in efficiency, productivity and profitability over the supply chain (Smart, 2010).

Several researchers have identified various enablers of EP system in their studies (Eadie *et al*., 2007; Farzin and Nezhad, 2010; Hawking *et al*., 2004; Matunga *et al*., 2013; Smart, 2010; Uddin, 2015). However, there is no any common classification for the drivers of EP adoption. Therefore, drivers were identified through literature which was characterised under five categories based on the nature of factors. Such categories include; Cost factors, Transparency factors, Time factors, Managerial factors and other general factors. Figure 2 shows the list of drivers identified under each category.

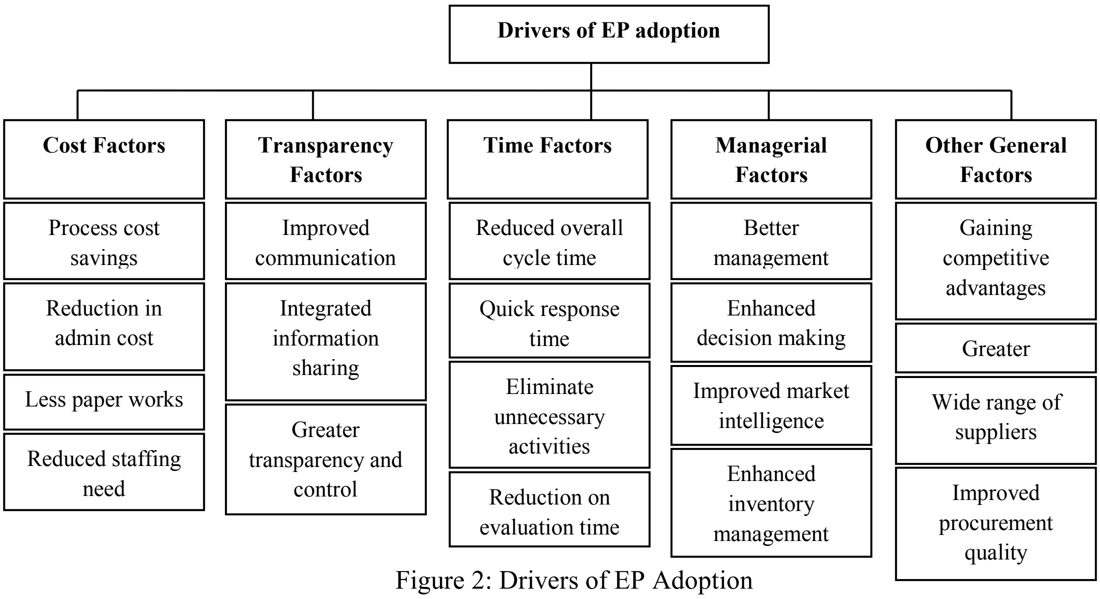

Figure 2: Drivers of EP Adoption

Cost factors mainly cover the driving factors which are directly relating to achieve the cost benefits to the organisation. It includes process cost savings, reduction in administration cost, lesser paper works, and reduced staffing need to facilitate the process (Matunga *et al.,* 2013). When it comes to the transparency factor, its scope focused on bringing out the transparency in EP system by making the procurement visible to all the relevant parties internally and externally. This category comprises factors which are enable the transparency in EP process i.e. improved communication, integrated information sharing and greater transparency and control (Smart, 2010). The third category is time factors where it deals with the time-based benefits achieved through the EP adoption in an organisation. This category consists reduced overall procurement cycle time, quick response time, eliminated unnecessary activities and reduction in evaluation time (Uddin, 2015).

Considering about the managerial factors, its scope relies on the management related returns attained through the adoption of EP system. Thus, it specially enables the management to have reliable system to compare the amount spend for purchasing with their allocated budget (Hawking *et al*., 2004). Better management, enhanced decision making, improved market intelligence and enhanced inventory management are fallen under this category (Hawking *et al*., 2004). The last categorisation is named as other general factors; include all the factors that are not fallen under aforementioned groups of driving forces. It comprises the sub factors i.e.

gaining competitive advantage, greater efficiency, wide range of suppliers and improved procurement quality as the other general factors of EP adoption (Farzin & Nezhad, 2010).

2.3. *BARRIERS OF E-PROCUREMENT ADOPTION*

Although transition to EP system brings together variety of benefits to the organisation, it has not been taken place as great as expected which argued by Davila *et al*.(2002). These deficiencies would be affected by numerous factors which are recognised by several authors (Davila *et al*., 2002; Eadie *et al*., 2007; Farzin and Nezhad, 2010; Matunga *et al*., 2013). Barriers are discouraging the organisations to adopt the EP system and become the obstacles to achieve the benefits from the EP system. According to the Davila *et.al* (2002), a list of barriers has been depicted under four broad category i.e. Internal risks, External risks, Technology risk and EP process related risk. The same categorisation is followed in this study. Figure 3 shows the sub factors comes under each category.

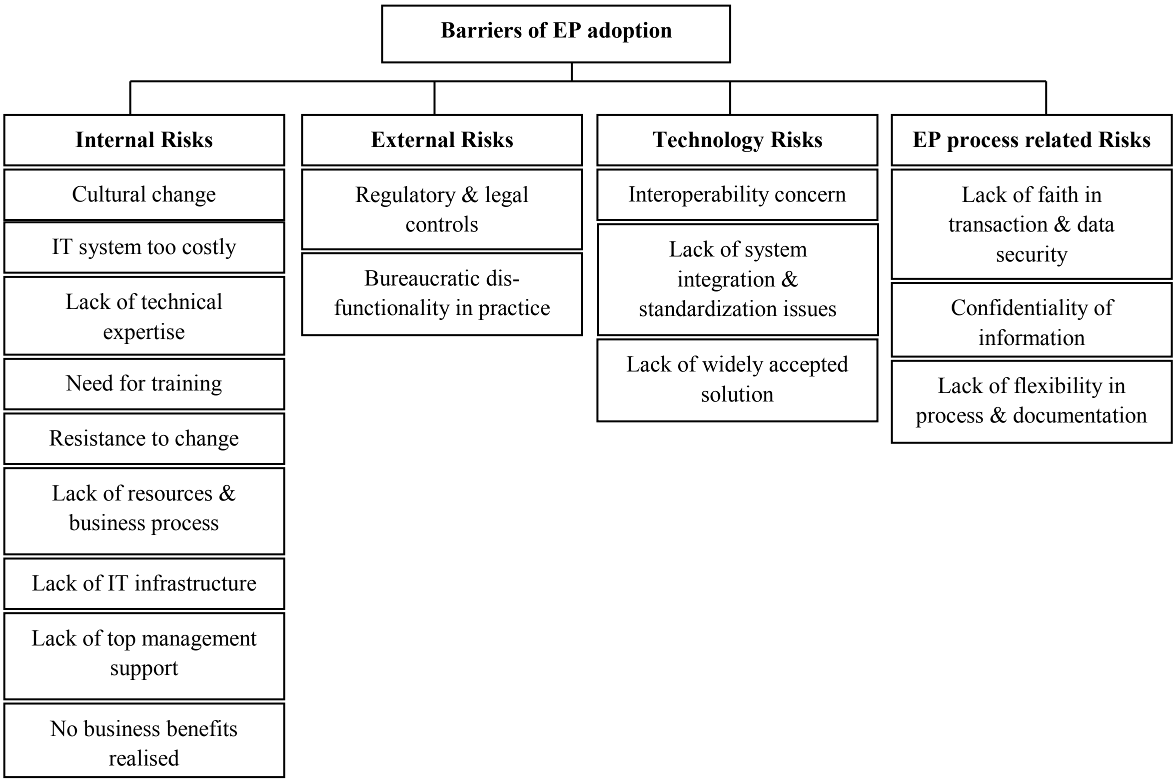

Figure 3: Barriers of EP adoption

Internal risks are the first category of barriers in EP adoption. According to Davila et.al (2002), integration of EP technologies with other business application such as accounting, human resources, accounts payable and cash management should give high concentration. Most of the companies have already implemented other business applications and the integration of EP should practice efficiently, otherwise it can be affect the trustworthy of the information of the organisation (Davila *et.al*. 2002). It includes cultural change, IT system too costly, lack of technical expertise, lack of knowledge, need for training requirement, resistance to change, lack of resources and business process, lack of IT infrastructure, lack of top management support and no nosiness benefits realised (Eadie *et al*., 2007). The second categorisation is the external risks which focused on solutions of EP need to be able to collaborate with supplier's IT infrastructure. Suppliers must be accessible through the internet and provide catalogues to satisfy the needs of their customers for EP solution to be successful. In order to provide the assurance to the buyers, organisations needed to develop a mechanism which helps the suppliers to meet the buyers' expectations with quality of services and delivery capability. It covers regulatory and legal control and bureaucratic dis-functionality in practice (Farzin and Nezhad, 2010).

Technology risks are the third categorisation (Davila *et al*., 2002). Most of the companies have uncertainty in the best suitable EP solution for the specific need. The integration of various EP solution is disrupted by the shortage of generally accepted standards. According to illustration of researchers, implementation of EP technology without broadly accepted standard for coding, technical, and process specifications will lead to slow and failure to obtain benefits i.e. interoperability concern, lack of system integration and standardization issues and lack of widely accepted solution (Matunga *et al*., 2013). The last categorisation is the EP process related risks. This category consists the risk of security and control of the EP process itself such as issues related to security and fraud (Davila *et.al.* 2002). Lack of faith in transaction and data security, confidentiality of information and lack of flexibility in process and documentation are depicted as the EP process-related risks (Farzin and Nezhad, 2010).

3. RESEARCH METHODOLOGY

The research design is a plan which should identify that particular task to be carried out by whom, when and how in order to complete the research process (Polonsky and Walker, 2011). This study was commenced with background study to identify the research problem and establish aim, objective, scope and limitation of the research. Then the literature review was carried out to identify the theoretical status of EP including nature of EP system, forms of EP applications, process re-engineering and identifying drivers and barriers of EP adoption. Having identified the research gap, researcher formulated the research question as "How drivers and barriers of EP adoption could be analysed to enhance the performance of procurement system in Sri Lanka?".

A qualitative approach followed to achieve the aim of research study in which case study approach was selected as research strategy. This is because, it allows the researcher to develop an in-depth analysis of a case, often a program, event, activity, process, or one or more individuals (Creswell, 2014) and analyse within each setting and the evidence created from this type of study is considered robust and reliable (Yin, 2003). The study was limited to four cases due to time constrains and limited information on EP practices in Sri Lankan context (Refer Table 1). Accordingly, twelve semi-structured interviews were conducted to collect the data in order to validate the drivers and barriers of EP adoption which were addressed through literature and to propose the strategies to strengthen the drivers and weaken the barriers of EP adoption. Three respondents from each case, who have involved in the procurement process, were interviewed (Refer Table 1)

Table 1: Profile of Organisation and Interviewee

Overview of Selected Cases				
Description	**Case A**	**Case B**	**Case C**	**Case D**
Nature of business	Telecommunication	Information technology	Health care	Banking
Ownership of the organisation	Semi government	Private company (Pvt)	Semi government	Private company (Pvt)
Location	Western province	Western province	Western province	Western province
Interviewees' profile				
Designation and interviewee code	Senior Procurement Manager - A1	Senior Manager Facilities - B1	Assistant General Manager - C1	Senior Operation Manager - D1
	Assistant Manager - A2	Associate Manager Facilities - B2	Mechanical Engineer - C2	Assistant Manager - D2
	Finance Manager - A3	Associate Consultant - B3	Finance Manager - C3	Finance Manager - D3
No of years' experience in the industry	A1 - 15	B1 - 12	C1 - 16	D1 - 10
	A2 - 10	B2 - 9	C2 - 13	D2 - 10
	A3 - 12	B3 - 3	C3 - 11	D3 - 5

Since the research contained four case studies of qualitative research, cross-case analysis used as it is the most preferable method of analysing multiple cases (Yin, 2003). The QSR.NVivo version 11.0 produced by QSR (Qualitative Solutions and Research Private Limited); computer software was used on this purpose. Finally, a model was developed for analysing the drivers and barriers of EP adoption based on the empirical findings.

4. RESEARCH FINDINGS AND DISCUSSION

The findings from four case studies were discussed under several sub-headings (refer Figure 4). Those heading includes divers of EP adoption, barriers of EP adoption and strategies to strengthen the drivers and weaken the barriers of EP adoption. Those will be the basis for following discussion.

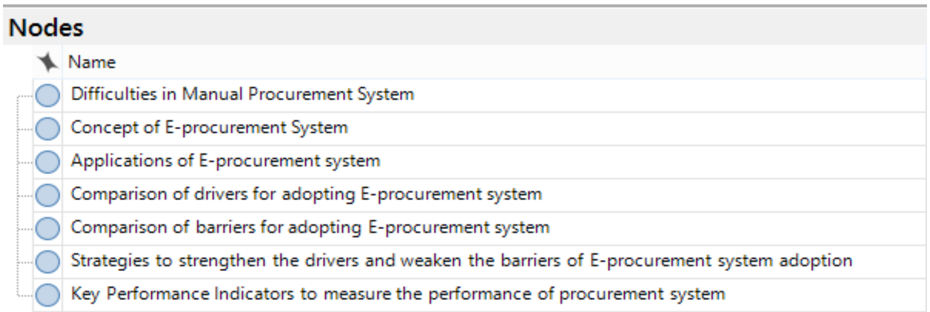

Figure 4: Structure of Study

4.1. DRIVERS OF EP ADOPTION

Empirical research findings manifested that factors which triggered the EP adoption vary from organisation to organisation based on the nature of the business and it further validated the literature findings. The below Table 2 shows the respondents' responses regarding the acceptance of identified drivers from the literature.

Table 2: Responses on Drivers of EP Adoption

Category	Drivers	Cases				Total
		A	B	C	D	
Cost Factors	Process cost saving	2/3	3/3	2/3	3/3	10/12
	Reduction in administration cost	2/3	3/3	2/3	3/3	10/12
	Less paper work	3/3	3/3	3/3	3/3	12/12
	Reduced staffing need to facilitate the process	3/3	3/3	2/3		8/12
	Reduced spacing cost*	3/3	2/3	3/3	2/3	10/12
Transparency Factors	Improved communication	2/3	3/3	3/3	2/3	10/12
	Integrated information sharing	3/3	3/3	3/3	3/3	12/12
	Greater transparency and control	3/3	3/3	3/3	3/3	12/12
	Improved contract compliance*	**3/3**	**2/3**	**2/3**	**1/3**	**8/12**
Time Factors	Reduced overall procurement cycle time	3/3	3/3	3/3	3/3	12/12
	Quick response time	2/3	2/3	2/3	2/3	8/12
	Eliminated unnecessary or wasted activities	2/3	2/3	2/3	2/3	8/12
	Reduction in evaluation time	2/3	2/3	2/3	2/3	8/12
	Short approval time*	**1/3**	**1/3**	**2/3**	**1/3**	**5/12**
Managerial Factors	Better management	3/3	2/3	2/3	2/3	9/12
	Enhanced decision making	2/3	2/3	3/3	2/3	9/12
	Improved market intelligence	3/3	2/3	2/3	2/3	9/12
	Enhanced inventory management	2/3	2/3			4/12
	Top management support*	**3/3**	**3/3**	**3/3**	**3/3**	**12/12**
	Operational level user's recommendation*	**1/3**				**1/12**
Other General Factors	Gaining competitive advantages	1/3	1/3	1/3	1/3	4/12
	Greater efficiency	2/3	1/3	1/3	1/3	5/12
	Wide range of suppliers	3/3	3/3	3/3	3/3	12/12
	Improved procurement quality	1/3	1/3	1/3	1/3	4/12

*Additions to the literature findings
(E.g: 2/3 shows that three out of two respondents from the case were agree the factor. There are twelve respondents selected in which three from each case was interviewed)

In addition to the drivers identified from the literature, five more drivers of EP adoption namely '**reduced spacing cost'**, '**improved contract compliance'**, '**less approval time'**, '**top management support**', and '**operational level user's recommendation**' were outlined through the case study findings are indicated Grey colour in Table 2. Among that top management support is mainly revealed by all the respondents from the selected cases though it was identified as a barrier in literature (refer Section 2.3). And the factor named as operational level users' recommendation was only asserted by Respondent A2 whereas all the others oppose the factor in because people at operation level do not like to change and they wish to work within their comfort zone.

4.2. BARRIERS OF EP ADOPTION

Even though the adoption of EP system is applicable in the industries, there are some factors which have become the challenge in applying the system in the organisations. Based on the empirical findings, seventeen barriers were finalised in total. These barriers were thoroughly analysed to propose the strategies to overcome the challenges and enhance the adaptability of EP system in Sri Lanka. Responses regarding barriers of EP system depicted in Table 3.

Table 3: Responses on Barriers of EP Adoption

* Additions to the literature findings

Category	Barriers	Cases				Total
		A	B	C	D	
Internal risks	Cultural change	3/3	3/3	3/3	3/3	12/12
	IT system too costly	3/3		3/3	3/3	9/12
	Lack of technical expertise	3/3		3/3	3/3	9/12
	Lack of knowledge	3/3		3/3	3/3	9/12
	Need for training requirements	3/3	3/3	3/3	3/3	12/12
	Resistance to change	3/3		3/3	3/3	9/12
	Lack of resources and business process to develop, implement and maintain	3/3		3/3	3/3	9/12
	Lack of IT infrastructure	3/3		3/3	3/3	9/12
	Lack of top management support**					
	No business benefits realised**					
External risks	Regulatory and legal control	2/3	2/3	1/3	2/3	7/12
	Bureaucratic dis-functionalities in practice			3/3	3/3	6/12
	Lack of suppliers' readiness*	3/3		3/3	3/3	9/12
Technology risks	Interoperability concern	2/3		1/3	2/3	5/12
	Lack of system integration and standardization issues	3/3		2/3	2/3	7/12
	Lack of widely – accepted solution	2/3		2/3	1/3	5/12
EP process related risks	Lack of flexibility in process and documentation	2/3	2/3	2/3	2/3	8/12
	Lack of faith in transaction and data security	3/3		3/3	3/3	9/12
	Confidentiality of information	3/3		3/3	3/3	9/12

** Eliminations from literature findings

(Ex: 2/3 shows that three out of two respondents from the case were agree the factor. There are twelve respondents selected in which three from each case was interviewed.)

According to respondents' responses, a new barrier shown in Grey colour which named as '**lack of suppliers' readiness'** was added, and two existing barriers shown in Black colour such as '**lack of top management support**' and '**no business benefits realised**' were eliminated from the list. In which lack of top management support was highlighted as a driver by interviewees. This is because, strategic decision to adopt new application taken by top management in the modern world (refer Section 4.1). Based on the opinion of respondents, strategies taken to strengthen the drivers and weaken the barriers of EP adoption were listed in Table 4.

Table 4: Strategies to Strengthen the Drivers and Weaken the Barriers of EP Adoption

Strategies	Description
Appoint a dedicated project team	▪ For selecting, planning, implementing, controlling and reviewing EP system. ▪ It assists successful adoption and continuous operation.
Continuously provide training for internal staff	▪ Conducting training programs to educate the people regarding EP system and its applicability to familiar with the new system.
Conduct real time testing	▪ Ensure the success of EP adoption through monitoring the difficulties in existing system and actions taken to resolve it. ▪ Undertake User Acceptance Test (UAT) to ensure the acceptability of user in the organisation.
Periodically conduct progress meeting	▪ At managerial level to share experience on problem encountered and solution taken to overcome.
Assign a consultant to manage the system	▪ From the service provider of EP software to solve the issue regarding coding and process specification.
Provide awareness program for suppliers	▪ To increase their knowledge on the system and its necessity and enhance their willingness to provide sufficient resources to move towards new techniques

5. A MODEL FOR ANALYSING THE DRIVERS AND BARRIERS OF E-PROCUREMENT ADOPTION

A model was developed finally incorporating findings of the study which will facilitate the successful adoption EP system in Sri Lankan organisations. The model includes both drivers and barriers which impact to the EP adoption as well as strategies to strengthen the drivers and weaken the barriers. Further applications of EP system and recommendations to improve the practice of all applications in Sri Lankan context are also depicted in the model (refer Figure 4). This model gives a clear tactic to the organisation to adopt the EP system by analysing the drivers and barriers to EP adoption in Sri Lanka. Thus, it assists the organisations to successfully implement the EP system to enhance the performance and efficiency of procurement system and the strategies founded in the research also insisting the organisations to adopt EP system by strengthen the drivers and weaken the barriers of EP system.

6. CONCLUSIONS

The increasing need and competitive nature of industries in the modern world have been forced the organisations to discover new solution or practice in adding the value to the businesses and enhancing the performance of procurement function. Most of the researchers were highlighted that EP is one of the innovative solutions which practiced by plenty of organisation all around the world to make the procurement process more efficient and they are questing new techniques to improve the use of EP system. However, the practice of the world is dramatically increasing, it is still in the initial stage in Sri Lanka due to the poor understanding on EP system and the factors influencing to successful adoption. Thus, this research attempts to develop a model for analysing the drivers and barriers of EP adoption.

This study was formulated four sequential objectives to achieve the ultimate aim of research consistently. In this empirical investigation, four cases who have adopt EP system in western province in Sri Lanka were selected on the purpose of analysing the drivers and barriers of EP adoption and seeking the strategies to strengthen drivers and weaken barriers of EP adoption in each case and compare them across the selected cases on how they impact on the successful adoption of EP system in their respective facilities. Finally, a model was developed based on the findings in order to facilitate the adoption of EP system in Sri Lankan context. The developed model will direct the organisations to increase the practice of EP system towards to enhance the procurement performance by presenting a comprehensive view of factors influencing to EP adoption.

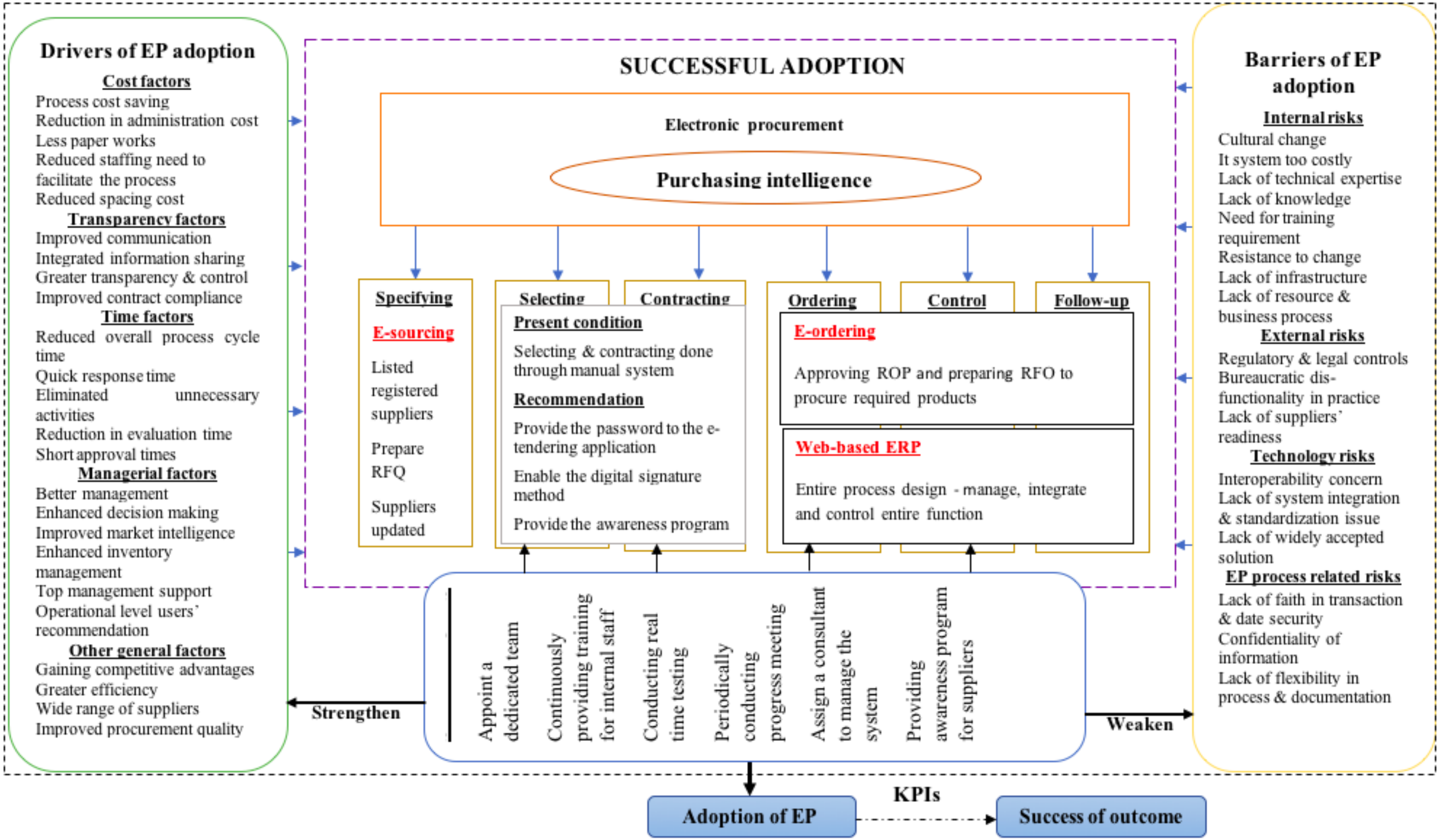

Figure 5: Model for Analysing the Drivers and Barriers of EP Adoption

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NEW APPROACHES TO EMPLOYER ENGAGEMENT WITHIN SURVEYING EDUCATION: DEGREE APPRENTICESHIPS

Andrew Ross and Mohan Siriwardena*

Department of Built Environment, Liverpool John Moores University, United Kingdom

ABSTRACT

Differing models of academia and the construction industry collaboration have evolved in the UK and internationally to develop a healthy skills supply chain. However, the increasingly popular Degree Apprenticeships in the UK has caused there to be much greater prominence of the issues around industry-academia interaction. Degree apprenticeships were part of an initiative introduced by the UK government in 2015 aimed at boosting employer investment in education and training. In April 2017, employers whose pay bill exceeded £3m had a 0.5% levy deducted, which was ring-fenced to support new apprentices.

This paper explores the tripartite structural issues that this new approach will need to address for the initiative to deliver the outcomes required by the Universities, employers and apprentices. The paper, inter alia, reports on an employer survey aimed at gathering opinion data. The data were collected from a survey designed to investigate employer's expectations of degree apprenticeships, their advantages and disadvantages and to ascertain the impact that the new approach might impact graduate recruitment in future. The survey findings and subsequent interpretation of results will be used to inform the strategic direction of the university's engagement with industry and with the degree apprenticeship initiative. Possible implications to future delivery of surveying education in the UK are also discussed including references to lifelong learning.

Keywords: *Degree Apprenticeships; Lifelong Learning; Professional Bodies; Surveying Education; University Industry Collaboration.*

1. INTRODUCTION

Developments in the area of employer engagement in academic degree programmes, have been inconsistent and difficult to predict. Although there are established models of industry-academia collaboration in different sectors such as IT (Gorschek, 2006) many of these relate to research interaction rather than skills and capacity building. The Degree Apprentice initiative is one of the first structured frameworks to formally drive the collaboration of industry and academia in large scale educational delivery.

This paper explores the tripartite structural issues that the new Degree Apprenticeships programme will need to address for this particular initiative to deliver the outcomes required by the Universities, employers and apprentices. Paper presents a background to the programme, research method for the study, the findings of the research and the implications for the future of the programme.

2. DEGREE APPRENTICESHIPS INITIATIVE

The development of bi-partite arrangements that support the effective engagement of academia with industry stakeholders has been an important aspect of built environment education in the UK (Ross & Riley, 2018). The engagement often occurred in an ad hoc manner with employer's representatives attending industrial advisory groups to consider curricula and employment trends. The nature of this engagement has often been fragmented and sporadic with employers tending to feed their skills supply chain needs through a mix of

*Corresponding Author: E-mail - m.l.siriwardena@ljmu.ac.uk

recruitment from full-time undergraduate programmes supplemented by staff development through part-time undergraduate programmes.

The new UK government pledged itself to continue with an ambitious programme of reforms to apprenticeships, which were set out by the previous government in 2015 and informed by the 2011 Wolf Review of vocational education. The Wolf review's (Wolf, 2011) findings impugned a system where too many apprentices were locked into dead-end jobs and where many high-quality apprenticeships were rare. The drivers behind the government's apprenticeship reforms are cited by the Skills Funding Agency (SFA) as being:

- A need to improve productivity through up-skilling
- A desire to force employers to invest more in high-quality training
- An ambition to improve social mobility and create more opportunities for young people
- The ongoing policy directives around getting universities and business to collaborate

As well as increasing the quantity of apprenticeships available, the government aimed to increase their quality by setting up the Institute for Apprenticeships (https://www.instituteforapprenticeships.org/). This new body, which was launched in April 2017, was made up primarily of employers who were responsible for setting the new apprenticeship standards, which were developed and proposed by employer consortia (Trailblazer groups) in consultation with educational providers.

3. DEGREE APPRENTICESHIPS MODEL

The programme involves a tripartite agreement. Parties to the agreement are the employers, university and the apprentice. In order to incentivise employers to invest in apprentices, an apprentice levy was introduced. This apprenticeship levy came into force on 6 April 2017, at a rate of 0.5% of pay bill, paid through PAYE and was only paid on any pay bill in excess of £3m. Only 1.3% of employers pay the levy and this 'tax' can be reclaimed through a digital account that supports higher-level training – and it is estimated that this will involve over 19,000 employers generating approximately £2.5b of Apprenticeship Levy Funds. Non-levy employers will be able to access the scheme through co-investing 10% of the cost of training and receiving a 90% government contribution

In order for employers to spend their apprentice levy contribution on degree apprentices, two components have to be available; these were an approved standard and an approved assessment plan. These prescribed behaviours, skills and knowledge that needed to be achieved by the apprentice on completion of the apprenticeship. Once these two components were approved the standard was "ready for delivery" Currently, in February 2018, 119 level 6 standards have been published with 44 ready for delivery, although far few are actually being delivered at present due to complexities with the apprentice standard assessment plans. (Ross & Riley, 2018)

The UK Government is not clear on whether the money raised via the levy will be entirely new money and how much will be available for degree-level apprenticeships. To a large degree this will be left with employers to determine – and some employers (particularly in the public sector, where resources are scarce) are expected to want to move quickly to recoup their levy contribution and invest in staff training. The financial structure of the DA model is generally favourable to universities. Although employers are encouraged to negotiate the best price for the training they require, funding is available for up to £27k of the cost of a Level 6 award (BA/BSc).This is the full cost of a UK, 5 year construction management degree. To incentivise completion of the apprenticeship and to encourage providers and employers to ensure that the end point assessment is achieved, a 20 % fee retention is held back until evidence is submitted to the Education Skills Funding Agency (ESFA) of satisfactory completion. It is anticipated that this will create a significant change to the relationship that Higher Education Institutions (HEI) have with their students. Under this new arrangement, they are required to monitor and support the apprentice and his employer upto 2 years after graduation.

On programme assessment approaches

The end point assessment for the chartered surveying standard is undertaken by the Royal Institution of Chartered Surveyors. It comprises 24 months of structured training and 24 hours of continuous professional development which are evidenced by a training log. The candidate also has to complete a reflective report on a case study indicating how competencies were practiced at the appropriate level. The training log of competencies and case study form the basis for an interview which if passed confirms completion.

4. BENEFITS OF THE DA APPROACH

The benefits to the learner/apprentice are that they gain a degree qualification and relevant work experience without building up significant debts, have excellent employability and earning power and the scheme contextualises learning by combining practical and theoretical perspectives. It also leads directly to membership of the relevant professional body. The benefits to the universities are that it provides additional learners, more structured employer engagement which is central to the aim of economic engagement with local industry and provides good evidence of local economic impact.

It has been posited that successful industry-academia collaboration requires ten success factors as follows:

- need orientation
- industry goal alignment
- deployment impact
- industry benefit
- innovation
- management engagement
- network access
- collaborator match
- communication ability
- continuity

(Sandberg *et al.,* 2011)

It can be argued, cogently, that the Degree Apprenticeship initiative inherently reflects these principles and should, therefore, have strong probability of success in the long term. The success of such collaboration has often been considered in terms of outcomes although with particular reference to the construction sector it is also essential to consider success in terms of impact.(Pertuze *et al.,* 2010) One of the possible implications of the initiative is the potential for disruption in the existing education al models that support the sector.

Much of the current literature investigate the demand side considerations such as need for greater enhancement of the skill base (National Audit Office, 2016), flexible learning opportunities, reducing the funding burden on students (Hall *et al.,* 2010) and greater fit with industry needs and higher employability. However, there is a clear gap in current literature on the supply side issues/challenges of HEIs when delivering such programmes.

Degree Apprenticeship (DA) offers the opportunity for universities to secure funding to recruit students from non-traditional backgrounds. The scheme is designed by employers, universities and professional bodies, which aims to deliver high-tech and high-level skills and offer an alternative to a traditional degree course (National Audit Office, 2016).

However, current accountability frameworks may result in an unnecessary confusion around the roles and responsibilities of individual actors associated with DA delivery resulting in a missed opportunity to maximise the value arising from the tri-partite delivery relationship (Lambert, 2016). In this instance the specific approach has been to encourage the employers to be part of this process. In the light of the current funding arrangements for HEI for England, universities may see this as a way of supporting the securing of student numbers. Sectors such as BE may also see this as rolling back the years, when the vocational education use to have a strong apprentice base.

Significant amount of literature highlights the need for apprentice schemes of various forms including DAs (Hall *et al.,* 2010; National Audit Office, 2016). Whilst recognising the increased presence of employer involvement (Phoenix, 2016), several supply side issue requiring further investigation has been cited in literature. Some of such aspects include questioning the suitability of current accountability standards of HEIs in relation to DAs (Lambert, 2016), factors affecting completion of apprenticeships in England (Gambin & Hogarth, 2015) and ascertaining the levels of success (Kirby, 2015). However, there is a dearth of literature with a critical investigation into how DAs affect the supply-side of BE HEIs.

This new approach to learner and employer engagement was considered potentially disruptive to the University and, in turn, the department whose current focus is primarily upon full time education. Approximately 17 % of the department's full time equivalent (FTE) undergraduate students were part time; these were almost exclusively studying one programme that had a long-standing tradition of "day release" education. It was considered that if the numbers of degree apprentices significantly increased and they became replacements for full time students that this would have a disruptive impact on the department's approach to teaching and learning, the organisation of the timetable, the deployment of academic resources to support the employer and apprentice during the apprenticeship. The impact this would have upon the resources was also exacerbated by the need to monitor the learners post-graduation. There would also be a significant impact upon the income generated as the tuition fee would be recovered over a six year rather than a three year period and there would be "lost fees" due to non-completion of the end point assessment and the retention of 20% of the fee. In order to explore this in more detail it was resolved to gather data from employers regarding their intentions to engage with this new initiative and whether they were considering moving from a graduate only recruitment policy to one that favoured degree apprenticeships.

5. RESEARCH METHOD

A preliminary literature review was conducted, and it highlighted the need for the development of the skills of the built environment and the related professional areas. A series of open interviews were carried out with four employer's representatives who were part of a programme industrial advisory group. The interviews were aimed at exploring awareness and attitudes to degree apprenticeships, the implications for employer HR departments, the perceived associated benefits and disadvantages and future recruitment intentions. Analysis of this data identified that there were a range of conflicting views of employer's attitudes to undergraduate education and part time employment and it was resolved to undertake a wider study involving additional participants.

A questionnaire survey was designed to investigate the attitudes of employers across five sectors, construction, digital, healthcare, engineering and other. The survey was designed to collect demographic data about the employer, size and sector and investigate the following areas using a Likert scale approach;

The employers awareness of the degree apprenticeship initiative:

This was aimed at establishing whether their recruitment practice of graduates had been adapted in light of the new levy introduction and to assess their likelihood of engaging with the initiative. The degree apprenticeship approach requires the employer to support the apprentice for a period of at least 6 years from initial engagement until completion of the end point assessment. This was perceived, in initial discussions with employers, as lacking flexibility when compared with their traditional practice of employing graduates and made the initial selection of the apprentice critically important. It was also perceived as having an inherent risk if the apprentice could not complete, due to a moral obligation to support a younger person, which was considered stronger than that due to a graduate.

The employer's opinion on the impact:

This refers to the fact that the apprentices were likely to have upon their business, their productivity and the implication of the requirement for an industrial mentor and whether this would have a positive impact on the organisation.

After piloting the survey with eight employers, amendments were made and distribution of the survey took place in April 2017. An email was sent with a link to the online survey to 215 organisations who had previously sponsored part time students or had registered an interest in employing graduates. This sample was primarily located within the north west of England within a catchment of 75 miles from Liverpool and was contained approximately 40% of small and medium sized enterprises and 60% larger employers. The survey was open for two weeks and which was extended by a further two weeks with two email follow up reminders.

6. Results and Discussion

31 organisations responded which represented a disappointing 14% response rate. The categories of respondent are shown in Figure 1. Small and medium sized enterprises (SME) employing 250 people represented 61% (n=19) of respondents.

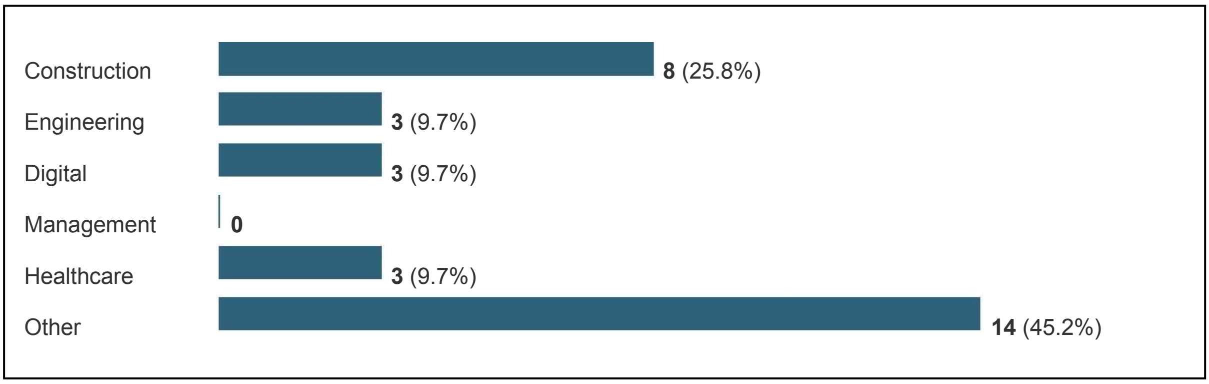

Figure 1: Categories of Employer Respondent to the Degree Apprentice Survey.

The survey sought to gather information on the employer's intentions to recruit graduates, a question regarding graduate recruitment sought the numbers of graduate recruited per year. Figure 2 indicates that the majority of the employers recruited 1-5 graduates per annum. The larger employers had a centralised recruitment policy and employed over 20 per year. The SME employers formed 91% of the respondents seeking 1-5 graduates, this was expected given their size.

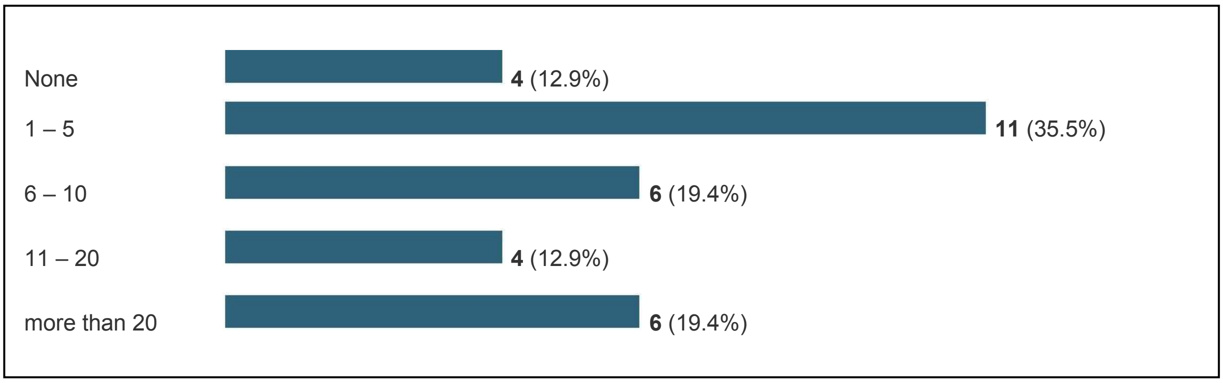

Figure 2: Number of new graduates employed per year

Employer awareness

In order to put the survey into context, data was gathered from the employers regarding their awareness of the degree apprentice initiative. The University had undertaken an intensive awareness raising campaign alongside a national campaign by the UK Government. A Likert scale was used to assess the level of awareness, which is shown in Figure 3.

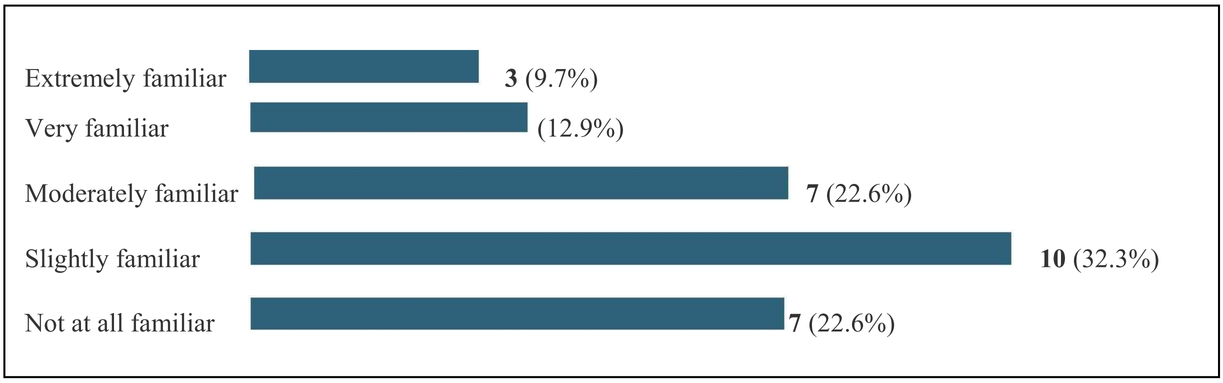

Figure 3: Level of Awareness of Employers of the DA Scheme

A minority of employers were very or extremely familiar with the scheme, these respondents were the larger employers with a dedicated human resources department who had been researching the impact that the apprentice levy may have upon their business. However, it is not clear at this stage whether these particular respondents have distinguished the DA scheme from the day-release scheme.

The employers were asked about how relevant they considered the scheme to their future intentions and as shown in Figure 4, 73% felt the scheme was highly or very highly relevant to their future recruitment needs. The respondents who indicated moderate or low relevance were all from the SME category.

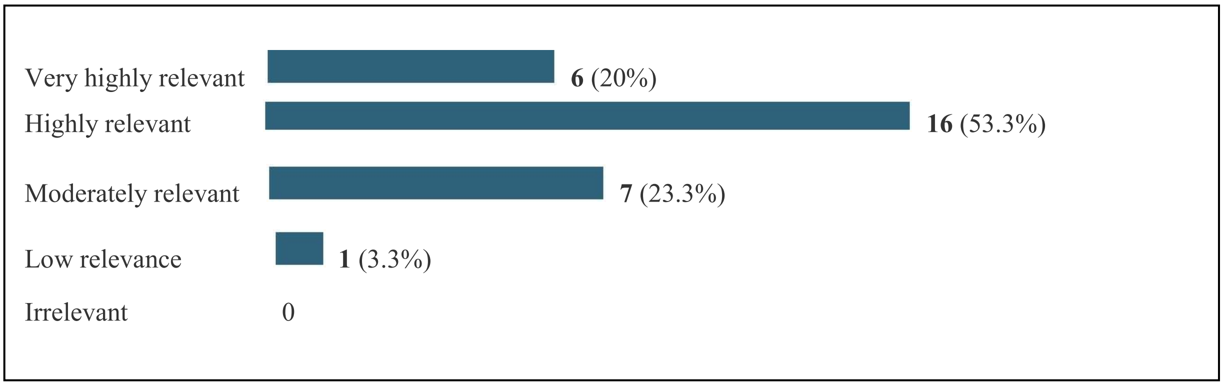

Figure 4: Relevance of the DA scheme to future graduate recruitment intentions.

Impact

Employers were asked about their opinions about the barriers that may hinder their engagement with the degree apprentice scheme. They were asked to rank the following barriers from 1-7, 1 being the most significant barrier.

These were that the DA programmes were too inflexible, required a long-term commitment to untested employees, required a change of approach to recruitment practices, required changes to existing human resource systems, required excessive time from industrial mentors, and required the apprentice to undertake the end point assessment.

The results indicated that the long-term commitment to an untested employee was the biggest disadvantage to the scheme, 39% of respondents raised this as either highest or second highest disadvantage; the employers in the SME category (70%) were over represented within these respondents. The next highest ranked disadvantage was the time required by industrial mentors to support the apprentices in the workplace, 26 % of respondents ranked this as the very significant or second highest. The SME organisations were under represented in this category (10%).

The other disadvantages were ranked as relatively minor by the respondents. The category of requiring professional body membership was ranked by 29% of respondents as the least disadvantageous possibly indicating that this was a major employer benefit of the scheme.

Perceived benefits

A similar series of questions sought information from employers about the benefits they perceived they would derive from engaging with the DA scheme. A Likert scale of 1-5 was used to seek their strong agreement (5) or disagreement (1) with a series of statements such as engagement with a student at an earlier age than a graduate, use of existing staff to support the apprentice and the apprentice being more likely to be loyal to the company

80 % (n=24) employers strongly agreed or agreed with the statement that the apprentice was likely to be more loyal than a graduate employee and remain with the organisation once the apprenticeship had been completed. This confirmed the views of the pilot group of interviewees who stated that graduates tended to have little loyalty to their first company and that the companies tended to experience proportionally higher churn amongst graduates than other employees. 73% (n=22) indicated strongly agreed with the statement that engagement with younger person would benefit their organisation. The open interviews conducted before the survey indicated that many employers felt that graduate tended to have high expectations in relation to their skills and productivity and that the employment of an apprentice that could be trained in the company methods would be

preferable. The majority of employers 70% (n=21) indicated their strong agreement or agreement with the statement that the use of existing staff to mentor their apprentices would provide a benefit to the company. This confirmed the findings of the open interviews were employers stated that tacit knowledge transfer from experienced employees to new starters would provide benefits to both parties via the formulation of practices.

The employers were less sure about whether an apprentice would be more productive than a graduate, 50% (n=15) indicated very strong or strong agreement with the statement that the apprentice would be more productive than a graduate would.

Support required

The employers views about the University's role in recruitment and support of the apprentices were sought . 81% (n=25) indicated that they would welcome the university taking a role in the recruitment of apprentices, 61% (n=19) indicated that they would engage with a post graduate support system for development of the graduate to the end point assessment, 50% (n=16) indicated that they would require assistance with their employee development programmes 19% (n=9) indicated that they would like support for the development of HR support systems. 42% (n=13) indicated that they would welcome support from subject specialists.

Unsurprisingly the SME employers indicated that they would require more support than the larger employers would and valued the subject specialists input higher than the larger employers. This possibly indicated the more transactional nature of larger employers with Universities when compared with the small organisations.

The survey results and ongoing discussions with employers suggest that the degree apprenticeship scheme will have a disruptive effect on undergraduate vocational education. Employers are likely to be seeking fast track degrees, which will require elements of work based learning and assessment. This will require Universities to become more agile in their approach to the design of these programme's curricula, this will need to also encompass approaches to quality assurance of the apprentices work place experience and homogeneity of work place competences across arrange of employers size and sectors. The implications for funding for University departments involved with the degree apprentice schemes is that the fees are recovered over a 6 year period rather than a 3 year (full time) or 4 year (sandwich) degree. In addition to this, the 20% fee retention until completion of the professional body's end point assessment (EPA)will require University's to track, monitor and support the graduate upto 2 years post graduation. The risk in fee loss due to apprentices not undertaking the EPA is considered high and, from anecdotal sources, Universities are seeking to pass this risk to employers.

The employers indicated that their recruitment practice of employing graduates will likely change, as they will need to ensure that they get value from their levy spend. The implications of this are that they will require entering into longer term and less flexible arrangements with younger employees. Their commitment to the apprentices will, in some cases, be up to 6 years that has consequences for mentoring, employment contracts and support for the professional body EPA. The results of the survey indicated that the employers welcomed the opportunity to engage existing staff in workforce development. It is too early to establish the impact of this in practice and this will form an ongoing research project with employers.

7. CONCLUSIONS

Degree apprentice programme is relatively new, hence too early to draw major conclusions on its success. However, it is a scheme has much to commend it as a new model of engagement between employer and university. It requires both sectors to develop a better understanding of the external and internal factors that influence their practices. Over time, this will develop into shared approaches to recruitment, education and support of the apprentices. Early reflections suggest that both sectors are entering into arrangements that are, as yet, fully mature. There needs to be rapid development of quality assurance practices in both sectors to ensure that the learning experience of the apprentice, the employers confidence in the scheme and the Universities' financial model. This will cause disruption and it is likely that the benefits of engagement will outweigh the disadvantages. The relatively long term between the academia and the industry also offers potential to facilitate lifelong learning through through-life studentships (Siriwardena et al., 2011).

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PERCEIVED NEGATIVE EFFECTS ON PROJECT STAKEHOLDERS FROM ADOPTING BIM IN SRI LANKA

Mohammed Thanzeem Irshad[1*] and H.S. Jayasena[2]

[1]Department of the Built Environment, Liverpool John Moores University, United Kingdom

[2]Department of Building Economics, University of Moratuwa, Sri Lanka.

ABSTRACT

Many Asian countries have adopted Building Information Modelling (BIM) technology in their projects. But BIM Level 2 has not been adopted by Sri Lankan construction industry yet. While there are number of studies on BIM in and for Sri Lanka, there is no prior research focused on 'Perceived Negative Effects on Project Stakeholders from Adopting BIM'. Among many challenges and barriers in BIM adoption, negative perception is a significant challenge. Understanding the negative perception of each key stakeholder is very important to a successful BIM adoption. Without knowing how significant the perceived negative effects are, formulating effective BIM adoption strategies are impossible. There is a need to develop the understanding, of how these negative perceptions affect BIM adoption in Sri Lankan construction projects and among the key project stakeholders. Therefore, the purpose of this study is to identify the key project stakeholders for BIM adoption and to verify the status of perceived negative effects of BIM among Sri Lankan construction project stakeholders. In order to identify significant negative BIM perception among different disciplines, a deductive research method and quantitative approach was adopted. An online questionnaire survey was conducted among 316 key project stakeholders comprising clients, consultants and contractors, to identify the significant negative effects of BIM. 49 completed the questionnaire. Descriptive statistical analysis using percentiles method was used to rank the significant BIM perceptions. The study finds that the perceptions on BIM among different disciplines are widely different. However, all disciplines firmly agree that BIM will not replace their profession.

Keywords: *BIM; Negative Effects; Perception; Sri Lanka; Stakeholders.*

1. INTRODUCTION

Building Information Modelling is known as BIM or often referred as BIM. Autodesk defines BIM as intelligent process in 3D (3 Dimension) model which helps Architecture, Engineering and Construction (AEC) professionals to plan, design and construct buildings and structures (Autodesk, 2017). The normal misconception about BIM is that individuals think BIM is only about technology and the 3D design but it's more than that. Sri Lanka is far behind on adopting level 2 BIM, compared to the other Asian countries. This is because there are many challenges and barriers, and negative perception is a significant challenge among them. Understanding the negative perception of each key stakeholder is very important to a successful BIM adoption. Without knowing how significant the perceived negative effects are, formulating effective BIM adoption strategies are impossible. There is a need to develop the understanding, of how these negative perceptions affect BIM adoption in Sri Lankan construction projects and among the key project stakeholders. Consequently, this study on "Perceived Negative Effects on Project Stakeholders from Adopting BIM in Sri Lanka" becomes interesting, it yields useful outcomes. Finding of the study is valuable because it will help the professionals, key stakeholders and change agents who want to implement BIM in Sri Lankan construction industry.

[*]Corresponding Author: E-mail - thanzeem.irshad@gmail.com

2. BACKGROUND

There are many definitions about BIM, all around the world each individual uses the definition according to their usage. In this study, BIM is defined following National Institute of Building Sciences (2007) as a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decision throughout the life cycle from inception to its demolition. In 1970s Building Descriptive System (BDS) was introduced by Charles Eastman and that was the foundation for BIM. Then in the 1980s ArchiCAD was developed in Budapest by Gabor Bojar and it was the earliest building specific BIM enable tool. Parametric Technology cooperation (PTC) in the end of 1980s released the technology call Pro/Engineer. Pro/Engineer was used for constraint based parametric modelling. In the year of 1997 the PTC company was split and Charles River software company was created by Irwin Jungreis and Leonid Raiz. Irwin Jungreis and Leonid Raiz started working on Revit. Later, in the year 2002 Revit was bought by Autodesk. There are other many BIM enabled tools which were introduced in the market such as Tekla and Bently at this time. BIM is not only about software it's an integrated system and process related to the information sharing, but there were issues how to interpret from one BIM enabled software to another different BIM enabled software, because different users follow different software according to their easiness. To deal with this issue, International Alliance for Interoperability (IAI) was created in 1994. They found and developed International Foundation Class (IFC) as a solution for the interpret issue. Later IAI developed as buildingSMART and OpenBIM. BuildingSMART has the custodianship of IFC files and OpenBIM represents the universal collaborative process of buildings such as design, construction and operation. Globally at least 150 BIM enabled tools are available which support IFC (Simpson 2013, pp. 7 & 8). Evidently, a significant advancement has occurred for construction information technologies during recent decades.

2.1. BIM CHALLENGES AND BARRIERS

Deutsch (2011) overheard that the General Services Administration's (GSA) Office of Project Delivery, director Charles Hardy saying "BIM is about 10 percent technology and 90 percent sociology". From this statement it is understandable that, BIM is not only about technology. That is the key reason why there are many challenges/barriers in BIM adoption.

Lindbald (2013) has mentioned some barriers to BIM adoption such as interoperability; perceptions of BIM from different stakeholders; poor match with user's need; changing of work process; risks and challenges using a single BIM model; legal issues arise from it; disinterest and lack of demand of BIM; fear of new roles and new working collaboration; cost spend for training of individuals and the time spent for it. Puolitaival and Forsythe (2016) have identified some BIM adoption challenges from their research study as:

1. Finding the balance between
    - Technology and process
    - Practice and theories
    - Traditional and emerging Construction Project Management[CPM]
2. Smoothing professional development of staff
3. Availability and appropriate resources for BIM

Because of these problems BIM adoption become troublesome. People response to BIM has caused hindrance to BIM adoption but people also have overcome some of these challenges and these challenges and barriers are related to people and their perception, so it has a significant impact towards successful BIM adoption.

3. PEOPLE'S PERCEPTION ON CAD AND BIM

The human factor plays a vital role when new technologies are introduced, especially in the case of BIM. Technology, software and file sizes become more easy to use and manage but people are influential elements, who will determine the success of BIM (Deutsch, 2011).

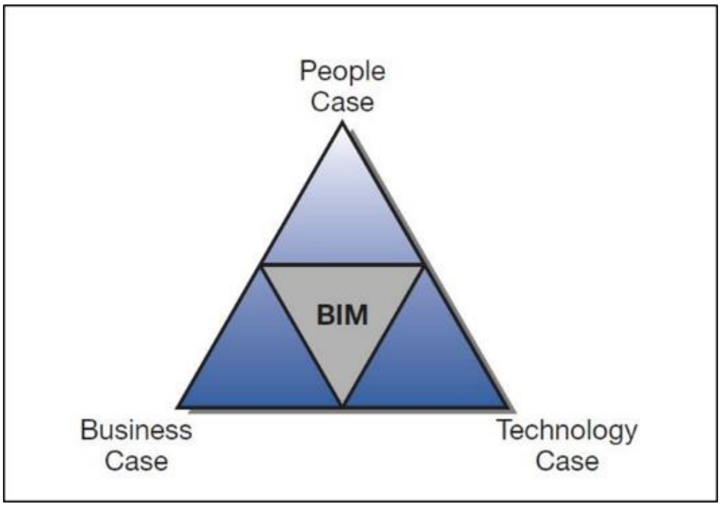

Figure 1: Peoples Influence on BIM

Source: Deutsch (2011)

Figure 1 shows that BIM is incomplete without people. Perception comes in to this heading since perception is interrelated with people's culture, attitude and practice.

Also computer aided design (CAD) and BIM are interrelated with each other. CAD was introduced in the late 1980's and some perceived that introduction of CAD can substitute Quantity surveyor profession (Sanders et al., 2007). But this perception was not true. Also some perceived that, the introduction of CAD will be a good opportunity for quantity surveyors to use it as a tool in design stage, but if those opportunities are missed, CAD can demise quantity surveyors' profession (Atkin et al., 1987). People may also have perceived variously for BIM as well.

3.1. KEY PROJECT STAKEHOLDERS FOR BIM ADOPTION

Project stakeholders are defined according to the Project Management Body of Knowledge (PMBOK, 2013) as "Individuals and organizations who are actively involved in the project, or whose interests may be positively or negatively affected as a result of project execution or successful project completion".

Some previous studies have identified the key project stakeholders for BIM adoption in the following Table 1.

Table 1: List of Key Project Stakeholders Influenced BIM Adoption from Previous Studies

No	Author(s)	Country	Project owner/ client	Architects	Quantit Surveyors	Contractors	Engineers	Some of them/ all
1	Kymmel (2008)	USA						x
2	Gu and London (2010)	Australia						x
3	Eastman *et al*. (2011)	USA	x					
4	Reddy (2011)		x					
5	Arayici *et al*. (2011)	UK		x				
6	Khosrowshahi and Arayici (2012)	UK						x
7	Keat (2012)	Malaysia			x			
8	Wijayakumar and Jayasena (2013)	Sri Lanka			x			
9	Eadie *et al*. (2013)	UK				x		

According to the Table 1, the key project stakeholders for BIM adoption as follows:

1. Project owners/client
2. Architects
3. Quantity Surveyors
4. Contractors
5. Engineers

3.2. NEGATIVE IMPACTS OF BIM ADOPTION AND IMPLEMENTATION IN PREVIOUS STUDIES

There are many previous studies on BIM and several authors have mentioned negative effects of BIM adoption in their relevant journals and books. These studies are ranging from 2011 to 2017 but not all books and journals related to the negative perceptions on BIM were referred but most of the negative perception has been identified through these journals and book. Most of the findings were through questionnaires, expert interviews and literature reviews. Those negative impacts are given in the following Table 2.

Table 2: Negative Effects of BIM Stated in Previous Studies with Relevant Authors

Author & Year	Identified Negative Effects of BIM
Deutsch (2011)	▪ BIM is extremely complicated and difficult to follow. ▪ BIM will overtake traditional way of designing. ▪ Working in BIM is not easy, have to learn lot of new skills and practices. ▪ Working in BIM may cause many technical difficulties. ▪ BIM will not give the expected Return on Investment (ROI). ▪ Allowing others to use BIM model and to edit it increase design liability risk. ▪ Difficult to learn BM applications. ▪ BIM change the way of workflow. ▪ Designers don't benefit from BIM like owners and contractors. ▪ BIM blurs the boundaries between design and construction. ▪ Can't rely on the dimensions obtained from BIM models for practical purposes
Azhar (2011)	▪ When using BIM model, it is not possible to identify who is responsible for if anything goes wrong. ▪ Data Ownership of BIM model is an unsolved issue.
Aibinu and Venkatesh (2012)	▪ Working with a BIM version would need to upgrade software, it is a huge cost to upgrade when new versions are released. ▪ Sometimes project documentation in old BIM files can't be imported into new BIM version. ▪ Upgrading to new version and even have to subscribe them may add additional cost to the firms. ▪ Information included in BIM models are not appropriate to allow automation of QS tasks. ▪ Lack of skilled employee who can work with BIM. ▪ If information assigned in BIM model is insufficient QS will have to return to manual quantity take-off. ▪ The end goals of the BIM models are different so the information are not easily reconciled to QS measurement. ▪ When insufficient and incorrect information input into BIM, QS may end up spending more time taking off and correcting quantities manually. ▪ Only a marginal or no time savings with BIM because significant portion of time will be spent on checking the accuracy of the model prior to quantity automation. ▪ When the models are erroneous the accuracy of estimate still remains the responsibility of the QS. ▪ BIM systems do not provide accuracy in measurement ▪ BIM can't communicate information in a level the subcontractors can interpret appropriately for pricing. ▪ Time need to learn the new way of working in BIM would affect the business. ▪ Designers are reluctant to share their model with QS.

Author & Year	Identified Negative Effects of BIM
Rogers et al (2015)	▪ Clients may not keen on paying design fees when shared BIM model is accessible to him. ▪ Government is not supporting its adoption.
Liu et al (2017)	▪ Unequal rewards of BIM among the other stakeholders. ▪ Restructure of the workflow. ▪ It is not worthy to pay for additional software and hardware cost, compared to benefits it brings. ▪ It is not worthwhile to invest as much time in design complicated 3D BIM models ▪ Various levels of project stakeholders may not have direct access to the BIM. ▪ Young staff with little experience will soon become skilled with BIM tools while experience veterans will have to rely on young staffs to operate BIM functions.
Herr and Fischer (2017)	▪ Practical standards and guidelines for BIM are not well developed

4. RESEARCH METHODOLOGY

4.1. DEDUCTIVE RESEARCH APPROACH

The deduction process always looks for ideas in text and through communication with others. The text can be journal articles, books and etc. Communicating with others such as colleagues and experts (Fellows & Liu, 2015). Usually a deductive research approach starts with a theory or generalised assumptions related to a hypothesis which will be tested through empirical observation which helps to decide whether to accept or reject that theory (Saunders et al., 2007; Bryman, 2012). In deductive approach, the theories or hypotheses will be tested using quantitative method. The deductive approach has been adopted for this study because the findings of negative effects of BIM has been identified in literature survey and based on that generalise theory was created. Then it will be tested among project stakeholders related to the construction industry using questionnaire survey.

4.2. QUANTITATIVE METHOD

Like, the nature of qualitative methods are 'subjective', the nature of quantitative methods are 'objective' (Naoum, 2006). Quantitative method are based on testing a hypothesis or a theory based on natural phenomena (Bryman & Bell, 2007). The process is based on studying the relationship between facts and theories and findings from previous research (Fellows & Liu, 2015). In construction management research studies, quantitative research method has been the dominant methodology (Knight & Ruddock, 2008). In quantitative studies the theory becomes a framework for the entire study and it helps to research questions or hypothesis and data collection procedure in the form of organizing a model (Creswell, 1994). The general quantitative strategies are: experimental and survey approaches such as questionnaire surveys. The negative impacts from previous studies as shown in Table 2 were converted in to questions and shared among 125 architects 30 quantity surveyors, 50 engineers and 111 participants of a recent BIM seminar which included a mix of professionals via email online. Among three different disciplines 17 architects, 25 quantity surveyors and 7 engineers responded to the questionnaire survey.

4.3. DATA ANALYSIS AND FINDINGS

Descriptive statistical analysis using percentiles has been used to rank the perceived negative effects statements from the respondents. All the perceived negative statements were ranked according to the following process. In order to rank the perceived negative statements: the minimum, 10th percentile, first quartile (25th percentile), median (50th percentile), third quartile (75th percentile), 90th percentile and maximum were identified individually for each statement. Then for the ranking process the statements were sorted out as in the first round the median which is 50th percentile was sorted within ties second round using 3rd quartile (75th percentile) sorted and within the ties 1st quartile (25th percentile) was sorted in third round, and further rounds sorting's were followed according to 90th percentile, 10th percentile, maximum and finally minimum respectively.

The equation to calculate the percentile is given below. This method is used to calculate PERCENTILE.INC in Microsoft Excel application. The Excel function was preferred over manual method in dealing with large amount of data.

$X = f(p,N) = p(N-1) + 1, p \in [0,1]$

$\therefore p = \frac{x-1}{N-1}, x \in [1, N].$

Note that $x \leftrightarrow p$ *relationship is one to one for* $p \in [0,1]$

Where, P= Percentile and N= Number in List

(Wikipedia, 2018)

Additionally, interquartile range (IQR) also calculated to understand how typical the median value is.

IQR = 3rd Quartile (75th percentile) – 1st Quartile (25th percentile)

5. BIM PERCEPTIONS

5.1. BIM PERCEPTION AMONG STAKEHOLDERS – GENERAL CATEGORY

The list of negative perceptions was ranked using descriptive statistical analysis using percentile. The stakeholders who participated in the questionnaire survey (architects, quantity surveyors and engineers) were asked to rate their level of agreement for a given statement in relation to each variable. The main purpose of the survey is not to identify the list of negative perception but to rank the significant negative perception that can influence the BIM adoption in Sri Lanka. Level of agreement included in the questionnaire as strongly disagree, agree, undecided, agree and strongly agree. In order to do the data analysis, level of agreement has been scaled -2, -1,1 and 2, where strongly disagree is -2, disagree is -1, undecided no scale, agree is 1 and strongly agree is 2. Ranking of the perceived negative effects of BIM relevant to all are given in Table 3.

The greatest significant negative perception of BIM among key stakeholders in general category are “Various levels of project stakeholders may not have direct access to the BIM”; “Practical standards and guidelines for BIM are not well developed”; “BIM is not possible because Sri Lankan government is not supporting its adoption”; “Young staff with little experience will soon become skilled with BIM tools while experience veterans will have to rely on young staffs to operate BIM functions” and all four of them has been ranked 1st. the fifth highest significant negative perception is “Time need to learn the new way of working in BIM would affect the business”, The most least significant negative perceptions are “BIM software applications are difficult to learn”; “BIM will not give the expected Return on Investment (ROI)” and “BIM technology and process is complicated and difficult to follow”. All three of them has been ranked 12th. However, analysis of the above for each profession showed quite different levels between them.

Table 3: Negative Perceptions Ranking of General Category

BIM perception statements	Min	10th Per	Q1	Median	Q3	90th Per	Max	**Rank**
General [Various levels of project stakeholders may not have direct access to the BIM]	-2	-1	1	1	1	2	2	**1**
General [Practical standards and guidelines for BIM are not well developed]	-2	-1	1	1	1	2	2	**1**
General [BIM is not possible because Sri Lankan government is not supporting its adoption]	-2	-1	1	1	1	2	2	**1**
General [Young staff with little experience will soon become skilled with BIM tools while experience veterans will have to rely on young staffs to operate BIM functions]	-2	-1	1	1	1	2	2	**1**
General [Time need to learn the new way of working in BIM would affect the business]	-2	-1	1	1	1	1.7	2	**5**
General [BIM will disrupt the present established workflow and therefore is difficult to adopt]	-2	-1	-1	1	1	1.3	2	**6**
General [Working in BIM is not easy, I have to learn lot of new skills and practices]	-2	-1	-1	1	1	1	2	**7**
General [Working in BIM may cause many technical difficulties]	-2	-1	-1	1	1	1	2	**7**
General [BIM blurs the boundaries between design and construction]	-2	-1	-1	1	1	1	2	**7**
General [When using BIM model, it is not possible to identify who is responsible for if anything goes wrong]	-2	-1	-1	-1	1	1	2	**10**
General [We can't rely on the dimensions obtained from BIM models for practical purposes]	-2	-1	-1	-1	1	1	2	**10**
General [BIM technology and process is complicated and difficult to follow]	-2	-1	-1	-1	1	1	1	**12**
General [BIM will not give the expected Return on Investment (ROI)]	-2	-1	-1	-1	1	1	1	**12**
General [BIM software applications are difficult to learn]	-2	-1	-1	-1	1	1	1	**12**

Min= Minimum, 10th Per= 10th Percentile, Q1= 1st Quartile, Q3= 3rd Quartile, 90th Per =90th Percentile, Max = Maximum

6. CONCLUSIONS AND RECOMMENDATIONS

The top most significant perceived negative effects common to all three professions are:

- Various levels of project stakeholders may not have direct access to the BIM
- Practical standards and guidelines for BIM are not well developed
- BIM is not possible because Sri Lankan government is not supporting its adoption
- Young staff with little experience will soon become skilled with BIM tools while experience veterans will have to rely on young staffs to operate BIM functions

However, ranking for these also varies among three professions.

6.1. RECOMMENDATION - GENERAL

"Practical standards and guidelines for BIM are not well developed" and "BIM is not possible because Sri Lankan government is not supporting its adoption" has been ranked as 1st most significant perceived negative effects of BIM in general category by different disciplines. This kind of similar findings were identified in several overseas studies. UK has already mandated the level 2 of BIM in 2016 and there has been improvements in BIM based projects. Countries like Singapore and Hong Kong are leading in BIM based projects in Asia. Somehow Sri Lank will adopt BIM but the government should drive the adoption within five years, because BIM is the future of construction. If the government can make BIM compulsory, the demand for BIM will increase but in order to do that construction bodies, industry associations and the government should make a joint effort to create and modify guidelines and practical standards for BIM and also should amend better laws and regulation on BIM.

In addition, the universities should add BIM to their curricula and provide more BIM courses to students which will help students to become familiar with BIM before they work in BIM based projects. So it will reduce the training cost and time which different disciplines perceived it as a significant negative effect of BIM adoption. The brainstorming sessions, Symposium and seminars must be conducted regularly all over the Sri Lanka to understand about BIM, rather than to think that BIM is just a 3D based CAD service, but BIM is not only about 3D it has other 'nD' capabilities which would help the stakeholders throughout the project lifecycle.

6.2. LIMITATIONS OF THE STUDY

Only the identified negative effects of BIM from literature survey has been used to conduct the research but there could have been other various negative effects of BIM not clearly identifiable from the previous studies which were not included in this this research. 14 negative perceptions discussed in this paper are the common effects identified as relevant to all. Unique effects to each profession are not discussed in this paper though they were studied in original study.

6.3. FURTHER STUDY RECOMMENDATION

To overcome this identified limitation of this study it is recommend to identify the negative effects from other previous literature and to be continued further.

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POTENTIAL OF APPLYING EARNED VALUE MANAGEMENT (EVM) AS A PERFORMANCE EVALUATION TECHNIQUE IN BUILDING CONSTRUCTION PROJECTS IN SRI LANKA

M.G.C. Ekanayake[1], H.S. Jayasena[2] and L.M.B.N. Kolugala[2*]

[1]Department of the Built Environment, Liverpool John Moores University, United Kingdom

[2]Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Construction industry has some unique characteristics that brings specific challenges in achieving required performance. Currently majority of construction companies evaluate the project performance by program review method, which can identify the performance after the activity accomplishment or action is accomplished. The project should have begun to use the existing performance technique. Earned Value Management (EVM) is a more robust, internationally recognized and adhering process to evaluate the project performance. EVM considers the performance in Time, Cost and Quality aspects. EVM compares the project Planned Value (PV), Earned Value (EV) and Actual Cost (AC). Current knowledge showed no evidence of EVM in Sri Lankan construction projects. This research was conducted to identify the potential of applying Earned Value Management (EVM) as a Performance Evaluation Technique in Building Construction Project in Sri Lanka. The research followed a qualitative approach. The researcher could be able to identify the facilitators, barriers and the challenges of applying EVM in current context. Semi-structured interviews were conducted to investigate status and key challenges for the implementation. After analysing the data, the researcher could conclude major barriers and challenges on implementing EVM as a performance evaluation technique for Sri Lanka construction industry. Its consumption of considerable extra cost, need to train staff, reluctance of some qualified employees to adhere to the technique due to various constraints could be identify as common bottlenecks.

Keywords: *Barriers; Earned Value Management (EVM); Facilitators; Sri Lanka.*

1. INTRODUCTION

The organizational value of carrying out project management is a vital theme involving much of the field's existing research and debate (Thomas and Mullaly, 2005). According to the viewpoint of Project Management Institute.EVM is one of most effective performance measurement tool and a feedback tool for managing the projects (Khan et al., 2010). The tool facilitates to close the loop in the plan-do-check-act management cycle in an effectual manner. EVM is known to be “Management with lights on” since it could aid straightly in an objective manner to identify the status of project and its progress compared to the planned (Anon., 2005). Evaluating the performance of a project alongside the lifespan of it is an approach to provide early cautioning indications which can be used as triggers for remedial arrangements in case the project is in jeopardy (Vanhoucke, 2011). In the past period various project-planning methods such as Gantt chart, Programme Evaluation and Review Technique (PERT) and Critical Path Method (CPM) have been developed (Anon., 2012). The Earned Value Project Management is a powerful tool that support the management to measure performance of the project and progress in objective manner. This tool can measure the performance and progress by using basic triple constraints such as project scope, time and cost (Anon, 2014). EVM considers the completed work amount, the time utilized to complete them and the costs sustained to accomplish the specified work and it aids to assess and regulate project risk by quantifying the project advancement in financial

*Corresponding Author: E-mail - nirmalakol91@gmail.com

terms (Vandevoorde and Vanhoucke, 2006). Numerous studies have been led relating to EVM by Fleming and Koppelman (2010) relating to the applicability of EVM and as a performance evaluation method with related to construction field. Relating to Sri Lankan context, a study has been conducted Hettipathirana and Karunasena (2014) about EVM as a performance measurement technique and its practice in Sri Lankan construction industry comparing with the traditional method of construction. However, its' potential on Sri Lankan construction industry to implement EVM considering enablers and barriers is discussed in this study.

2. RESEARCH METHODOLOGY

In order to identify the potential of applying Earned Value Management (EVM) as a performance evaluation technique in building construction project in Sri Lanka, a qualitative approach was applied. Thus to proceed with the qualitative approach, a sample of six number of expertise were selected from contracting and consulting organizations among the professionals such as Planning Engineers and Quantity Surveyors. In depth, interviews were conducted to examine the status of the facilitators and barriers to apply EVMS in Sri Lankan construction Industry. This mainly focused to find whether EVM is using within Sri Lankan context and to identify major requirement and challenges to implement this technique in Sri Lankan construction industry. Collected data was qualitatively analysed and interpreted under identified themes categorized as facilitators or barrires of EVM to arrive at conclusions. Table 1 represents the respondent profile of the conducted interviews.

Table 1: Respondent Profile

Organization	Respondent	Type of Organization	Designation	Years of experience
01	R1	Consulting	Planning Engineer	Less Than 5 Year
01	R2	Consulting	Quantity Surveyor	5 – 10 Years
03	R3	Contracting	Planning Engineer	5 – 10 Years
04	R4	Contracting	Quantity Surveyor	5 – 10 Years
05	R5	Contracting	Planning Engineer	Less Than 5 Year
06	R6	Consulting	Planning Engineer	5 – 10 Years

3. EARNED VALUE MANAGEMENT AS A TECHNIQUE

The PMI delivers a historical outlook on the advancement of EVM technique departing from the primary efforts with PERT/COST method. Major advances are the integration of planning, control and delineation of project scopes into a single tool (Anon., 2014). The Earned Value method has been developed as a tool which aiding control of the project progress. It has been used to determine the status of the project and the measure of current variances from the plan (Czarnigowska, 2008). This tool could measure the performance and progress by using basic triple constraints such as scope of the project, time and cost. It allows the calculation of cost and schedule variances and performance indices and predicts the project cost and schedule at completion (Andari, 2003). With respect to Anon (2012) EVM concept is a comprehensive management approach that once integrated on any kind of program, even if in research and development, construction or production offers all levels of management with a prior view into cost and schedule problems. Thus EVM is currently used on programs worldwide. According to Usmani (2012) three major elements of EVM are identified as Planned Value (VE), Earned value (EV) and Actual Cost (AC) and their terms explanations were identified as follows (Fleming and Koppelman, 2010).

- Planned Value: Entails of the certified work, alongside with the approved budget, within the approved time duration, which completely formulates the project baseline.
- Earned Value: Includes the approved work that has been finished, along with the original budget for the work.
- Actual Costs: Contains the actual costs sustained to transform the Planned Value into the Earned Value.

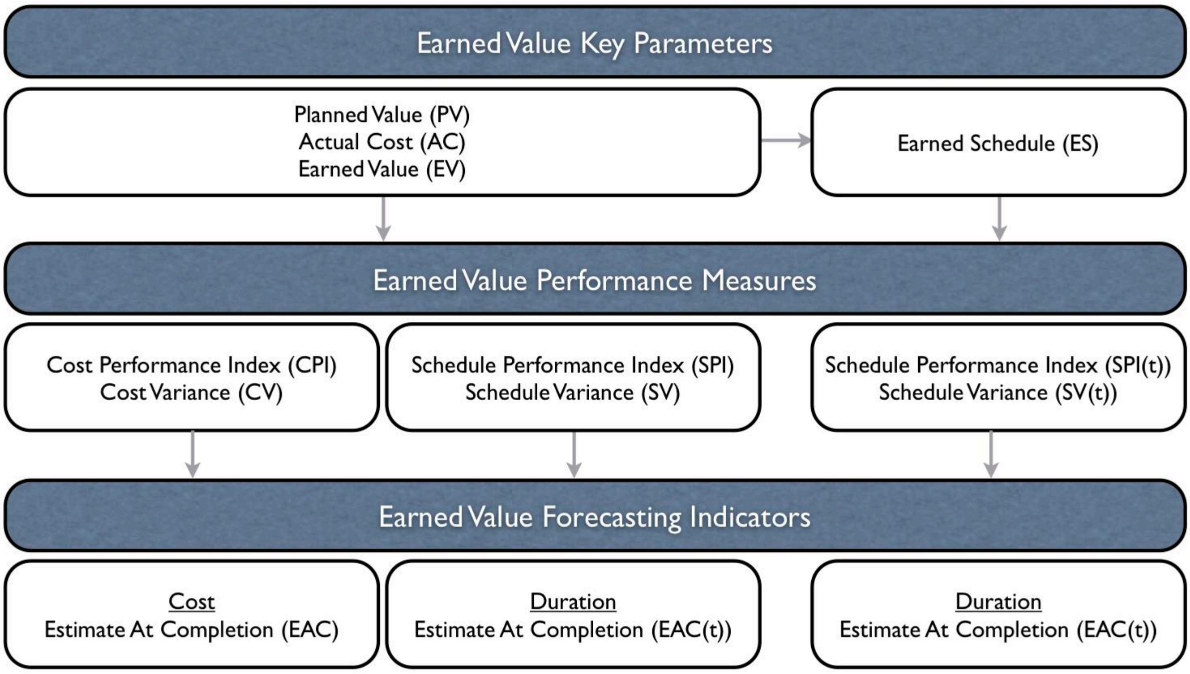

Figure 1: Three Main Components of EVM

Source: (Vanhoucke, 2011)

Project managers may adopt a value-engineering program for cost saving whichever by decreasing scope and quality in certain divisions of a project or offer supplementary budget to conceal the overrun cost. Correspondingly, in a situation of time overrun, they might plot some program such as fast-tracking or time crashing to suite situation through the reduction of time. Thus, the role of EVM as well as precise and on time predicting is extremely significant to attain project goals. Following Figure 2 will give clear identification about this technique and advantages of practicing this. Appraisal of those figures could aid to detect exact work packages in which performance and advancement are insufficient or advanced, which will optimistically lead to counteractive action by the project manager and team. Cost and schedule performance should be evaluated and analysed as viable with consistency and intensity consistent with project management need including the magnitude of performance risk.

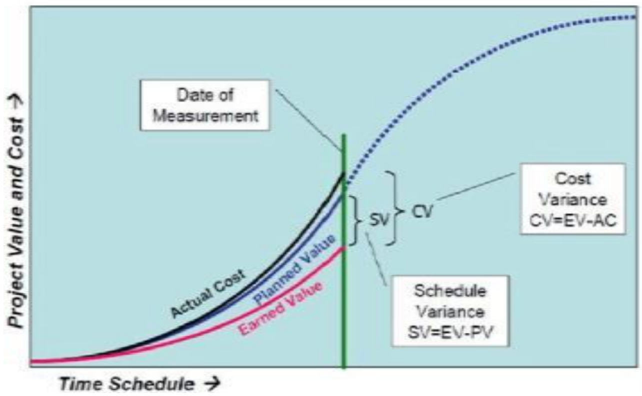

Figure 2: Standard Earn Value Analysis Graph

Time and Cost constraints could be interpreted by the key parameters indicators. By using parameters evaluation of the performance could be done through the performance calculation formulas. Mainly using Planned Value (PV), Actual Value (AC), Earned Value (EV) and Earned Schedule (ES), which results in the following performance measures (Anon, 2017).

3.1. TIME PERFORMANCE

The Schedule Performance Index (abbreviated as SPI or SPI (t) dependent on whether EV or ES is used) is a measure to explicit the current time performance of the project, presenting whether the project is progressing beyond the schedule (>100%), on time (=100%) or late (<100%).

3.2. COST PERFORMANCE

The Cost Performance Index (abbreviated as CPI) is a measure to convey the present time performance of the project, showing whether the project cost is below budget (>100%), on budget (=100%) or above budget (<100%) (Vanhoucke, 2011).

3.3. FORECASTING MEASURES

The project time and cost performance measures are expected to be an illustrative indication for impending project performance, and thus it could be utilized to predict the ultimate project duration and cost.

- **Time forecasting:** The Expected at Completion - Time (abbreviated as EAC (t)) is a prediction of the final project duration at the status date, given the current project performance. Clearly, this prediction might vary from the baseline Planned Duration (PD).
- **Cost forecasting:** The Expected at Completion - Cost (abbreviated as EAC) is a prediction of the entire cost of the project at the status date, given the current project performance. Perceptibly, this prediction might be diverse from the original budget or Budget at Completion (BAC).

Project performance measures can be reevaluated as of below. When the project CV=0 & CPI=1 and SV=0 & SPI=1 the project is executing expected schedule as well as expected budget. The performance measures with respect to cost and schedule components are illustrated in Figure 3 as follows.

PERFORMANCE MEASURES		SCHEDULE		
		SV >0 & SPI > 1	SV =0 & SPI = 1	SV <0 & SPI < 1
COST	CV >0 & CPI > 1	Ahead of Schedule Under Budget	On Schedule Under Budget	Behind Schedule Under Budget
	CV =0 & CPI = 1	Ahead of Schedule Under Budget	On Schedule On Budget	Behind Schedule On Budget
	CV <0 & CPI < 1	Ahead of Schedule Over Budget	On Schedule Over Budget	Behind Schedule Over Budget

Figure 3: Performance Measurement Interpretation of EVM

Source: (Prashanth and Raja, 2014)

4. FACILITATORS OF EMV

EVM supports to project managers and team members to gain early cautionary indications that let them take well-timed actions. It will helpful for project success. EVM can be utilized for progress payments to contractors based on the EV of contracted or outsourced work. Thus, the identified enablers within the current context of Sri Lankan industry is illustrated in the following Table 2.

Table 2: Enablers to Implement EVM in Construction Projects

Enablers to implement EVM in construction projects	
Enable to utilize as a Progress Evaluation Technique	Although several progress measurement techniques are currently available in the construction industry no proper method is utilized to measure progress accurately which enable to use EVM as an effective method to measure progress successfully.
EVM offers early signal	For the evaluation of the progress in a project, it is required to attain prior notification for project managers. Thus, if it is not available in the current practices, EVM can be introduced to gain an early signal for upcoming events.

Enablers to implement EVM in construction projects	
Early Planning is required to utilize this technique	Planning is included in the prior stage of the project and if there is a lack of proper planning in the execution of the project then progress evaluation could not be adopted suddenly. Hence, projects must consist of decent early planning where EVM can be executed to measure progress.
Ability to execute in a project with a good collaborative teamwork	A competent teamwork is required to run a project successfully where objectives will be achieved on time. Through the cooperative team, EVM could be implemented within the project to attain the required progress.
Should consist of Reliable Data	With the availability of the reliable data it is easy to apply EVM for the evaluation of performance.
Enable to utilize as a cost management tool	EVM could deduce early alerts on cost overruns which are financially advantageous to the project enabling EVM to use as a cost management tool.
Less documentary utilization	Most of the organizations utilize documentation irrespective of their necessity. Hence the use of EVM software enable the reduction of documentation.
Enable in the intensification Employees skills	With the application of EVM software employees could improve on certain skills.
The demand of the company would be increased	New implementation of EVM within an organization would add extra value for the company while increasing the demand of the organization.
Helps to build an effective communication in between employees	Effective communication build a good interrelationship in between employees thus a new technique like EVM would increase the strength of the bond through employees.
Relate the current status of the project	With EVM project managers could identify project status very early which could be a positive factor against to barries.
Ability to use as a good management tool	EVM help to manage those parameters of the projects on the aspects of time, cost and quality.

5. BARRIERS AFFECTING TO THE EVMS

Sri Lankan construction industry required a well-known and established performance monitoring technique for the development of the industry and for its better performance. Consequently, it is vital to investigate the applicability of introducing EVM as an effective performance indicator for the construction industry. However, currently, SriLankan Project Managers are exercising several types of tools to measure their performance. Nevertheless, it could be identified that the knowledge on the usability of the technique and outcome to be achieved and its reliability is lack among the management due to their poor knowledge on the awareness of the EMV. Thus, with the analysis as represented by Table 3, the identified barriers and their current status could be represented in a comprehensive manner.

Table 3: Barriers Identifed within Sri Lankan Construction Industry for the Implementation of EVM

Barriers	Status
EVM perform	EVM covers a large area and with the limited within Sri Lankan projects, employees do not interest in doing additional work.
The struggle of Employees	Lacks a rigid bondage between employees and management results in the lack of adherence of EVM in their projects.
Cost factor	Most of the project managers are not risk taking with a new technology with the note of high cost involved in the implementation of EVMS in a project.
A Longtime period for the execution and implementation of the EVM	Due to the lack of expertise in the industry more time is required in acquiring required knowledge and skills in the EVM software.
Accuracy of data	Lack of reliable data in the construction industry in a major hindrance which required regular monitoring to acquire them for the productive implementation of EVM.

Barriers	Status
Lack of awareness on EVM	Most of the employees not compatible with EVMS due to their lack of awareness which results in the construction projects to use them.
Fear for language	Lack of knowledge on the English language act as a hindrance for the employees to embrace and utilize EVM in Sri Lankan context.
Minimum support from the top management	Some managers do not like to share their knowledge with the middle, lower level employees. It may be the cause for newly implementation.
Technical issues	Since Sri Lanka is lack of technical facilities required IT physical and human resources should be available for a project to implement EVMS.
Demotivation of the employees	Motivation and encouragement of the employees are required within the employees for the implementation of EVMs, however within Sri Lankan context demotivation appeared to be a considerable barrier for the EVM implementation.

Thus, for the efficacious application of EVM as a performance evaluation, discussed facilitators and barriers should be minimized. Hence the several actions could be implemented to enhance the possibility to adopt EMV within Sri Lankan context while utilizing the top management supports effectively. The introduction of training programmes about EVM would surpass the lack of awareness about the EVM among the employees while enabling more expansion towards its development. Additionally, though the improvement of skills in the information technology this could be further enhanced as it motivates the employees for its adaptation. Effective communication between parties could introduce an organization friendly environment where the whole organization would move on to adherence to EMV without any hindrances. Introduction of a support team would enable an organization to upsurge with additional aid during the implementation stage of EVM.

6. Implications of the Study to Industry and Knowledge

The potential of applying EVM to the construction industry is high once the barriers to the implementation are mitigated. The enablers of the EVM emphasis on the benefits of it to the construction industry as a performance indicator and hence, it would be favourable for them to utilize it as a management tool. Consequently, the construction and contracting organization would be benefited in the utilizing of EMV with the required technical knowledge and capital investments. Thus, required training sessions with knowledgeable professionals would aid to increase the knowledge of the employees. Additionally, EVM is identified to be a cost management tool which would enhance the resource management of a construction project.

7. Conclusions and Recommendations

Through the extensive analysis conducted during the research, it was identified that there are facilitators and barriers for the implementation of EVM as performance technique within Sri Lankan context. Through conducted semi-structured interviews along 13 facilitators of EVM application have been identified and 10 existing barriers to the EVM application has been spotted out. Thus, it is clear that the current condition of Sri Lanka could be improved by mitigating the barriers identified in the survey since several enablers are existing for the upsurged potential within the industry.

Hence it is required to implement EVM within the capable construction organizations, enabling them to experience them through undertaking required training, facilities and with a cooperative environment.

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PROFITABILITY ASSESSMENT OF SOLAR PV INSTALLATIONS IN SRI LANKAN RESIDENTIAL BUILDINGS

S.R.M.P. Senevirathne*

Department of Quantity Surveying, University of Vocational Technology, Sri Lanka

ABSTRACT

The study focused on developing a cost recovery model to evaluate the profitability of installing solar panels in buildings in Sri Lanka to address the growing demand on the electricity supplied from the national grid. The study aimed to make the buildings in Sri Lanka zero carbon buildings. A cost-benefit analysis model was developed using Microsoft Excel to assess the profitability of solar power panels. The model was applied for a sample consisting of 8 domestic (small to large) consumers, to identify the type of domestic consumers most suitable for installing solar panels. Using the standard electricity tariffs enforced by the Ceylon Electricity Board, the average annual costs of electricity consumed by eight consumers were computed along with their Net Present Values (NPV) for a period of 25 years based on the interest rates offered by banks in Sri Lanka, to identify the discounted annual cash flows and evaluate the recovery period of high initial costs of solar power panel installations. The model shows that when solar panels are installed in buildings with high power consumption their high initial installation costs could be recovered in a relatively short period of time. Therefore, the installation of solar penal in such buildings would be profitable.

Keywords: *Cost Benefit Analysis; Net Present Value (NPV); Zero Carbon Buildings; Zero Carbon Economy.*

1. INTRODUCTION

Large scale hydro and thermal power plants are the main sources of electricity generation in Sri Lanka (Ceylon Electricity Board, 2018). The commercial and residential sectors in the country consume a significant amount of electricity generated. Of the total electricity consumption of the country, 24% is consumed by the commercial sector while as much as 40% is consumed by the domestic sector (Arachchige, 2004).

In the past two decades, Sri Lanka has used various sources to generate energy (Ceylon Electricity Board, 2018) mostly hydro power sources. Thus, the power generation in Sri Lanka is highly dependent on the annual rain fall rate which is quite unpredictable. The annual rainfall of the period from 1961 to 1990 has decreased by about 144 millimetres (about seven per cent) from the annual rainfall of the period from 1931 to 1960. The annual rainfalls recorded at the meteorological stations in Baticaloa, Kurunegala, and Rathnapura have shown high variations (Chandrapala, 1997). Because of the decreasing annual rainfall and the unpredictability of the rainfall pattern, the demand on carbon fuel based electricity generation has increased significantly in the recent times (Ceylon Electricity Board, 2018). Sri Lanka annually imports 2 MMT of crude oil, 4 MMT of refined petroleum products and 2.25 MMT of coal, which altogether cost approximately 5 billion USD which is 25% of the total expenditure on imports and almost 50% of the total income received from exports. These imports mainly intended for use by the transport sector meet 44% of the energy requirements of the country (Rodrigo, 2015).

In 2013, a year which had good rainfall, 50% of the electricity generated was from hydro power, 9.85% from Non-Conventional Renewables (NCR) (mini-hydro, wind, biomass and solar) and the balance from thermal plants. There was less rainfall in 2014, and as a result, the contribution from hydro power sources dropped to 29.4%. Since the contribution from NCR sources remained unchanged, the balance of over 60% was generated

*Corresponding Author: E-mail - srmpseneviratnaunivotec@gmail.com

by using oil or coal plants owned by the Ceylon Electricity Board (CEB) and supplemented by private power plants that used oil (Gunawardana, 2016). According to Ceylon Electricity Board (2018), carbon based energy sources provide 27.95 GWh (81.04%) of electrical energy and hydro and other clean energy sources provide a minimum of 6.54 GWh (18.96%). There is a increasing tendency to use carbon based sources for energy generation, which release high amounts of CO_2 to the environment, a significant negative deviation from the current global trend of adopting de-carbonized economic concepts (European Commission, 2011). Wiseman and Edwards (2012) have focused on an economy using low carbon power sources to ensure minimal emissions of Green House Gases (GHGs) to the environment and eliminate global warming. Several alternatives have been identified during the last decades to achieve a zero carbon economy, thus paving way for renewable energy capacity to grow worldwide at annual rates in the range of 10–60 per cent and for promoting technologies involving wind, tidal, solar and biomass.

Therefore, during the last few decades in Sri Lanka, there has been a growing concern on the need to adhere to 'zero carbon energy economy' especially in the building sector. In this context, it will be necessary to reduce the dependence on carbon based energy sources. Therefore, the focus should be on implementing the 'zero carbon energy economy' concept along with the development of new clean energy sources such as wind, tidal, solar and biomass. Consumers such as offices and residences who have high electricity consumption need to seriously consider switching over to clean energy sources.

Sri Lanka being a tropical country has good potential for utilizing solar energy for electricity generation which will be even sufficient to meet the entire electricity demand of the country. Solar radiance in the country fluctuates between 5.5 and 6.5 kWh/m^2/day on clear sky days (NREL, 2018).

However, since the initial/installation cost of solar PV Panels is high, a financial analysis will be necessary to determine the viability of having solar panels as a clean energy source for electricity generation. Therefore, the need arises for a market focused financial investment model to assess the costs and benefits of solar Photovoltaic (PV) cells.

Before using solar PV technology, it is necessary to identify the category of consumers who are best suited to make use of this technology. According to Sustainable Energy Authority of Sri Lanka (2010), domestic sector in Sri Lanka consumes 40% of the total energy consumption of the country while commercial and industrial sectors consume 24% and 34% respectively. Thus, the domestic sector was considered as the most significant sector to this study. The cost-recovery model to be developed can evaluate the profitability and the recovery period of the high initial/ installation cost of solar PV which is a net zero carbon alternative to the conventional power supply fed from hydro-power and diesel powered energy sources.

The study focused on developing a Microsoft–Excel Spread Sheet giving a profitability index to identify the most suitable type of domestic consumers (from among those who have low, mid and high electricity consumption) who can use solar panels for their energy needs. Finally, an analytical approach was developed to determine the recovery period (within a period of 25 years which is the life time of solar PV panels) of the high initial investments made on solar panels. The study further recommends that policies be formulated to enable the move towards globally led low carbon society that would considerably reduce greenhouse gas emissions.

2. LITERATURE REVIEW

2.1. CONCEPT OF ZERO CARBON ECONOMY

As the probability and risks of climate change continue to grow, there is a very urgent need for a swift transition towards a strong zero-carbon economy (Nader, 2009). Global GHG emissions are highly dependent on climatic conditions. According to Watson (1997), in the next century, the global economy is expected to turn into a fossil fuel-intensive economy. Low-carbon economy (LCE), low fossil- fuel economy (LFFE), or de-carbonized economy is an economy based on low carbon power sources that have minimal emissions of GHGs into the biosphere. This specifically refers to GHG emissions of carbon dioxide. Thus, in order to avoid catastrophic climate changes, steps need to be taken to embrace the concept of zero-carbon economy (Low Carbon Innovation, 2010; IRENA, 2012).

2.2. LOW-CARBON ECONOMY (LCE)

Moves towards zero carbon energy have come into place as a result of the paradigm shift in the global economic policies such as the strategies proposed for moving towards a holistic low-carbon economy with low carbon emissions (Rogelj, 2012). In industrialized countries like Australia, USA, Canada, Finland, France, Germany, Sweden, Norway and the UK, low-carbon energy concepts, renewable energy policies, and energy efficiency strategies are incorporated into national policies to achieve rapid reductions in unwanted emissions. These concepts, policies and strategies have emerged mainly due to the tendency that exists to transfer private capital to a low carbon society through GHG emission reductions. However, efficiency improvements, lifestyle changes, technological developments, policy designs, and demand reductions also need attention in this regard (Rogelj, 2012).

In developing an economic policy accommodating the concepts of low carbon economy, a certain degree of emphasis has to be on 'business models' that will facilitate behavioural changes. As a result, proposals for low-carbon economy should have an element of social innovation in a wide scale to change public behaviour towards a low-carbon society. Nishioka and Ishikawa (2012) highlight the potential that 'green growth' policies have for economic recovery through a low carbon society approach.

2.3. POLICIES ON ZERO CARBON ENERGY ECONOMY

Renewable sources including solar help to achieve the goal of bringing atmospheric carbon dioxide equivalent (CO_{2e}) to 350 ppm or below, and to rapidly bring down CO_{2e} emissions to zero along with carbon sequestration. As a result of the global trends that exist towards low carbon transition, low carbon roadmaps have come into the picture, with more energy effective strategies to promote renewable energy sources such as solar PV, wind, water (hydro, wave, tidal) and geothermal. For a more successful approach for a global energy system with 100% renewable energy, fossil fuel subsidies have to be removed and carbon taxes introduced. Nishioka and Ishikawa (2012) have further stated that taxes and tariffs can be incentives for behavioural changes of the public required for low-carbon development. Moreover, the increasing investments made in low carbon technology innovations have promoted the de-carbonizing of the energy supply to meet emission reduction goals.

The focus of the Governments of Australia, Germany, Denmark, Wales and the UK and the European Commission is on reducing GHG emissions during 2020-2050. To encourage zero carbon emissions, market based mechanisms such as rejecting 'transition fuels' (e.g. gas) and 'transition technologies' (e.g. more efficient petrol cars), higher prices on carbon, increased investments, incentives for innovation, commercialization and governance improvements of renewable energy have been adopted while promoting energy efficient technologies, systems and grid connectivity. In addition, cost-effective expansion of renewable energy sources and efficiency improvements have been proposed to foster their usage. With the current level of energy demand, the need has arisen for higher efficiency in power systems, electrification, decarburization through renewables and biomass. The integration of renewables and low-carbon energy sources is considered as secondary. In the coming years, the focus will be on the erection of wind turbines or solar plants in every town with more than 1000 high energy consuming people, reduction of deforestation and logging and the cessation of coal power plants (Nishioka and Ishikawa, 2012).

2.4. SOLAR POWER AS AN ALTERNATIVE TO CARBON BASED ENERGY SOURCES

According to Irena (2012), solar PV is the fastest growing renewable energy technology and is expected to play a major role in the future in the global electricity generation mix.

High Cost of Solar Photovoltaic Technologies

Solar PV technologies can be used anywhere provided the required solar exposure is available. The technology offers a number of significant benefits such as zero fuel costs and relatively lower operation and maintenance (O&M) costs (Green Match, 2017). IRENA (2012) states that unlike conventional power plants that use coal, nuclear, oil and gas, solar power as an alternative source of power can control carbon emissions. Even though solar panels can be expensive in the short run, once installed in contrast to conventional electricity supplies they will have no operational costs (Green Match, 2017). The maintenance cost of the system can be perceived as an additional cost, but in reality, the maintenance of solar panels includes only removing dust and/or washing (Borenstein, 2008). Moreover, according to Borenstein (2008), to encourage consumers to help in meeting the high initial cost of PV panel installations, the Energy Policy Act has been enacted in USA, establishing a new commercial federal tax incentive scheme for residential investments on renewable energies.

2.5. SOLAR POWER GENERATION IN SRI LANKA

Under Soorya Bala Sangramaya program of the Government of Sri Lanka, it is expected to add to the energy grid by 2020, 220 MW of clean power, which is about 10% of the country's current daily electrical consumption, and by 2025, 1,000 MW (Ministry of Power and Renewable Energy, 2016). Twenty per cent % of this energy is expected from solar power. However, currently, the installation of a solar panel with a capacity of 1 kWh will cost around LKR 200,000. Investing this amount of money upfront will be economically feasible only to those who consume 200 kWh or more. A guaranteed tariff for consumers who supply energy to the national grid using solar PV through what is called net accounting has also been proposed. Thus, the consumer will be paid if the solar PV power he generates is greater than what he consumes from the national grid creating a win-win environment for the two parties concerned.

At present, because of the multi-tier tariff system in force, those users who consume up to 30 units of electricity during a month pay LKR 7.85 per unit while those who use more than 180 units have to pay LKR 45 per unit (Gunawardana, 2016). Solar energy consumers will be paid during the first seven years LKR 22 per unit (1 kWh) for the excess solar power they generate and LKR 15.50 from the eighth year onwards (Gunawardana, 2016).

2.6. COMPONENTS OF A SOLAR PV SYSTEM

A solar PV system will have a breaker panel with circuit breakers that will interrupt the supply to appliances if they draw high currents that can cause fire hazards (Lowder, 2016).

2.7. ECONOMIC EVALUATION OF THE OPTIONS AVAILABLE

A cost benefit analysis will evaluate the benefits and costs of different options available. Among the common economic evaluation models such as Life-Cycle Cost Analysis (LCCA), Net Savings (or Net Benefits), Payback Period, Net Present Value(NPV), Savings-to-Investment Ratio (or Savings Benefit-to-Cost Ratio), and Internal Rate of Return (IRR) available to assess the benefits of different options, the Net Present Value (NPV) method was used to calculate the recovery period of the two options: conventional electricity supply and solar PV installation.

2.8. COST BENEFIT ANALYSIS USING NET PRESENT VALUE (NPV)

Net present values for different discount rates can be obtained by using the concept of time value of money . The concept involves the calculation of the future value of the present money component/ amount that is spent/invested today, against a discounted amount of cash flows coming in after a given time period (Storesletten, 2003).

$$NPV = -C_0 + \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + \dots + \frac{C_T}{(1+r)^T}$$

$-\,C_0 = Initial\ Investment$
$C = Cash\ Flow$
$r = Discount\ Rate$
$T = Time$

$$NPV = -C_0 + \sum_{i=1}^{T} \frac{C_i}{(1+r)^i} \qquad \text{Eq. (01)}$$

Cash outflows such as the initial investment are denoted with negative figures in order to identify the profitability of a project/ investment. Thus, net present values have to be positive (the sum of discounted cash flows), for a project to be profitable (Storesletten, 2003). In this study, the present value of investment for each solar panel option was calculated for 25 years using a formula generated with Microsoft Excel and provided in electronic format for the benefit of future users.

3. METHODOLOGY

Because of the high initial costs of solar panel installations, it was necessary to first identify based on their power consumptions the buildings in which it will be profitable to have solar panel installations.

As among the different types of electricity consumers, the highest percentage of the total electricity consumption is identified by domestic consumers (40% of the total consumption) (Ministry of Power and Renewable Energy, 2016), a random sample of eight domestic users with low, medium and high electricity consumption were selected for the study. Their average electricity consumption and the related cost were computed by averaging the corresponding figures given in their monthly electricity bills spanning a period of 12 months, to develop a financial model for profitability analysis. Table 1 presents the standard CEB billing rates that were used to derive the value of the mean annual bill for each case for the years 2016-2017.

Table 1: The Standard CEB Billing Rates (Available from :http://www.ceb.lk:accessed on 18/05/2018)

RANGE	Monthly consumption(kWh)	Unit Charge(Rs./kWh)	Fixed Charge(Rs./Month)
0-60	0-30	`2.50	30.00
	31-60	4.85	60.00
61->180	0-60	7.85	N/A
	61-90	10.00	90.00
	91-120	27.75	480.00
	121-180	32.00	480.00
	>180	45.00	540.00

Table 2 presents the monthly electrical consumption of the samples and their average monthly costs and average annual costs (for year 2014-2017).

Table 2: Monthly Electrical Consumption of a Random Sample of Eight Domestic Users

Months	Monthly electrical consumption and cost of the consumers															
	1		2		3		4		5		6		7		8	
	kWh	Rs.	kWh	Rs.	kWh	Rs.	kWh	Rs.	kWh	Rs.	kWh	Rs.	kWh	Rs.	kWh	Rs.
1	53	184	81	677	71	568	69	561	84	2,690	108	2,260	225	5534	487	17324
2	51	179	73	570	72	591	73	570	80	1,070	113	2,379	253	5984	425	14534
3	62	491	61	221	68	551	73	570	117	2,594	98	2,022	185	3734	472	3734
4	73	570	64	515	65	534	72	582	106	2,253	108	2,327	234	5534	539	19664
5	54	191	73	570	55	189	81	677	110	2,534	108	2,327	323	9944	215	5084
6	52	184	87	737	55	196	180	3,449	108	2,260	113	2,379	305	9134	458	16019
7	48	160	68	555	65	521	78	647	113	2,379	87	1,747	268	3960	567	20924
8	50	170	78	647	51	182	69	561	98	2,022	88	1,851	302	8999	477	16874
9	54	191	180	3449	63	501	78	647	108	2,327	128	2,736	235	5984	540	19709
10	54	191	72	582	62	226	64	515	108	2,327	101	1,277	317	9674	496	14220
11	53	184	72	582	63	591	78	647	113	2,379	118	1,935	256	6929	543	16335
12	62	491	78	647	51	315	73	570	87	1,747	175	3,516	206	4679	489	17414.00
YEB (Rs)	**3,187.12**		**9,751.20**		**4,964.25**		**9,479.25**		**26,582.50**		**26,757.00**		**80,0089.00**		**181,835.00**	
Avg. kW	**55.50**		**82.25**		**61.75**		**82.33**		**102.67**		**112.08**		**259.08**		**173.75**	
AMC(Rs	**265.59**		**812.60**		**413.69**		**789.94**		**2,215.21**		**2,229.75**		**6674.08**		**15,152.00**	

YEB(Rs) -Total annual electricity bill; Avg. kWh- Average monthly consumption; AMC (Rs) –Average monthly electricity bill

A cost recovery analysis model was developed to evaluate the profitability and the time taken to recover the initial/installation cost of the solar power panels using Microsoft Excel. The values derived were then used for the cost recovery analysis calculations pertaining to annual electricity consumption. Table 3 presents the average prices of the essential components of solar-PV panels: solar panels, charger controller, and inverter.

Table 3: Average Selling Prices of the Essential Components of Solar-PV Panels, of Seven Randomly Selected Suppliers

	Supplier prices												
	Solar panel				Charger controller (MPPT*)				Inverter				
Supplier		kWh	Brand	$	Rs.	A	Brand	$	Rs.	V	kWh	$	Rs.
	1	100	Brand S1	107	16,589	70	Brand CC1	153	23,705	230	Brand In1	259	40,156
	2	320	Brand S2	95	14,729	60	Brand CC2	269	41,826	220	Brand In2	440	68,219
	3	100	Brand S3	57	8,837	40	Brand CC3	113	17,520	220	Brand In3	155	24,025
	4	250	Brand S4	89	13,799	60	Brand CC4	261	40,311	220	Brand In4	199	30,853
	5	300	Brand S5	108	16,744	30	Brand CC5	262	40,500	220	Brand In5	91	14,186
	6	325	Brand S6	130	20,155	30	Brand CC6	156	23,415	220	Brand In6	202	31,319
	7	300	Brand S7	150	23,256	40	Brand CC7	95	14,729	220	Brand In7	50	7,752
Avg.					**16,301**				**28,858**				**30,830**

Since the average lifetime of a conventional solar panel is 25 years, the assessment done was for a period of 25 years. The average monthly electricity bill was computed using the electricity bills of twelve consecutive months. The value obtained was used to compute its net present values of each year for a period of 25 years for cost recovery analysis using Microsoft Excel. The average monthly consumption from the conventional system was then used to identify the number of panels required, the total cost of the panels, and the initial cost of the solar panels including the costs of batteries, charger controller and converter.

The consumption (kWh) was discounted for 25 years. Each value was separately discounted at 8%, 10%, 12% and 14% based the average deposit rates offered in Sri Lanka during the period 2011 - 2017. Table 4 presents the Key economic indicators for the Deposit rates during 20111 to 2017(CBR Sri Lanka-KEI.pdf- PART-1)

Table 4: Key Economic Indicators - Deposit Rates - (CBR Sri Lanka-KEI.pdf- PART-1)

Deposit rates	2011	2012	2013	2014	2015	2016	2017(a)
Commercial Bank Average Weighted Deposit Rate (AWDR)	7.24	10.10	9.37	6.20	6.20	8.17	9.07
Commercial Banks Average Weighted Fixed Deposit Rate (AWFDR)	8.95	13.21	11.78	7.33	7.57	10.46	11.48
NSB Saving Account Rate	5.00	5.00	5.00	5.00	5.00	4.25	4.00
NSB 12 month Fixed Deposit Rate	8.50	12.50	9.50	6.50	7.25	11.00	11.00

Based on the figures given above, the discount rate was taken as ranging from 8% - 14%, and these rates were used to identify the recovery period of solar power panel installations. If the present value for a particular year is negative for the rates considered (8%, 10%, 12& 14%), the investment in solar panel for that year will not be beneficial considering the internal rate of return.

4. DATA ANALYSIS AND FINDINGS

Table 5 presents a sample of the MS Excel model developed based on the findings of the cost-benefit analysis of the data obtained from the eight samples. Accordingly, the initial Recovery period for the initial cost of Solar-PV Panels was identified for each of the case.

Table 5: Recovery period of the initial cost of Solar-PV Panels

(Sample Case 08: Average monthly consumption: 173.75 Wh)

Avg. monthly consumption (Wh)	**173.75**				
Cost of the solar panel (Rs)	**16,301.00**				
Number of panels	**2**				
Total cost of the panels (Rs)	**32,602.00**				
Cost of batteries (Rs)	**10,000.00**				
Cost of charger controller (Rs)	**13129.00**				
Cost of charger converter (Rs)	**28716.00**				
Cost of installation (Rs)	**0.00**				
Total cost (Solar)	**114,447.00**				
1	114,447.00	105,969.44	104042.73	95,372.50	81747.86
2	114,447.00	98,119.86	94,584.30	91,236.45	88,063.25
3	114,447.00	90,851.72	85,985.73	81,461.11	77,248.47
Total cost for a conventional system					
	Total initial cost of a conventional system based on the yearly electricity bill (discounted for cumulative savings)				
	Discount rates				
No. of years	**-**	**8%**	**10%**	**12%**	**14%**
1	34,278.48	31,739.33	31,162.25	28,565.40	30,068.84
2	68,556.96	90,515.88	87,820.90	83,218.59	82,821.20
3	102,835.44	172,149.96	165,082.69	156,414.82	152,232.19
4	137,113.92	272,932.79	258,733.34	243,553.20	233,414.64
5	171,392.40	389,579.58	365,154.54	340,805.85	322,430.48
6	205,670.88	519,187.12	481,250.39	445,005.12	416,131.37
7	239,949.36	659,195.26	604,382.35	553,546.02	512,024.09
8	274,227.84	807,352.03	732,311.66	664,302.05	608,157.14
9	308,506.32	961,682.00	863,148.45	775,552.52	703,025.28
10	342,784.80	1120457.70	995,306.83	885,920.05	795,489.36
11	377,063.28	1,282,173.67	1142321.36	994,316.73	884,709.08
12	411,341.76	1,445,523.14	1,273,387.52	1099,897.92	970,086.81
13	445,620.24	1,609,376.78	1,402,467.83	1,202,022.58	1,051,220.61
14	479,898.72	1,772,763.59	1,528,840.16	1,300,219.36	1,127,865.23
15	514,177.20	1,934,853.69	1,651,930.10	1,394,157.61	1,199,899.65
16	548,455.68	2,094,942.68	1,771,290.03	1,483,622.62	1,267,300.27
17	582,734.20	2,252,437.63	1,886,580.88	1,568,494.55	1,330,118.84
18	617,012.60	2,406,844.44	1,997,556.03	1,648,730.62	1,388,464.25
19	651,291.10	2,557,756.45	2,104,047.33	1,733,424.25	1,442,487.79
20	685,569.60	2,704,844.18	2,196,688.74	1,813,023.53	1,480,871.31
21	719,848.10	2,847,846.14	2,293,962.22	1,887,647.85	1,526,816.38
22	754,126.60	2,986,560.56	2,386,603.63	1,957,449.51	1,569,038.26
23	788,405.00	3,120,837.99	2,474,651.26	2,015,624.31	1,607,758.48
24	822,683.50	3,250,574.63	2,558,174.69	2,065,849.75	1,643,200.33
25	856,962.00	3,375,706.43	2,637,268.85	2,116,259.09	1,675,585.06

With no discount, the investment in solar panels will be profitable only after the 3rd year (with the cumulative savings as added to the capital for each year). For discount rates of 8% 10% 12%, and 14%, the investment (with cumulative savings) will be profitable after the 3rd year which means that the investment will bring in positive cash flows only after the 3rd year.

Table 6 presents the recovery period calculated over internal rate of return for 25 years. (MEB-Monthly Electricity Bill (Rs.), YEB-Yearly Electricity Bill (Rs.).

Table 6: Recovery Period over Internal Rate of Return (8%, 10%, 12%, 14%) for 25 Years

Case	Average monthly consumption-(Avg) kWh	Monthly electricity bill (MEB)(LKR)	Annual electricity bill (Avg.)YEB (LKR)	Recovery Period (within 25 years) (Years)				
				No discount	8%	10%	12%	14%
1	55.50	265.59	3187.12	Not recovered	10.0	10.0	10.0	9.0
2	61.80	413.69	4964.28	Not recovered	8.0	8.0	8.0	8.0
3	82.25	812.60	9,751.20	Not recovered	16.0	15.0	15.0	14.0
4	82.30	812.60	9,751.20	Not recovered	16.0	15.0	15.0	14.0
5	102.7	2,215.21	26,582.52	8.0	7.0	4.0	4.0	4.0
6	112.1	2,229.75	26,757.00	8.0	4.0	4.0	4.0	4.0
7	149.2	3,063.33	36,759.96	6.0	3.0	3.0	3.0	3.0
8	173.8	2,856.54	34,278.48	7.0	3.0	3.0	3.0	3.0

The model developed was adopted to identify the period of recovery within a period of 25 years, which is the expected life span of solar PV panels, of the investments made in solar panels by the consumers.

The results show that even though the difficulty in recovering the initial cost is considered as a major constraint for moving towards a green energy economy, residential buildings with high electricity consumption have a higher potential for recovering the high initial cost of installation within a relatively short period of time. Therefore, residential buildings with high electricity consumption are recommended for installing solar PV panels because of the profitability.

5. CONCLUSIONS AND RECOMMENDATIONS

The study proves that in comparison to other users, domestic users with high electricity consumption are capable of recovering within a short period, the relatively high initial costs of solar PV installations. Therefore, for households with high electricity consumption in a country like Sri Lanka which has a tropical climate with the solar radiation on clear sky days fluctuating from 5.5 to 6.5 kWh/m^2/day, solar PV panels can be highly recommended. The study further recommends investments in solar PV panels as they are quite profitable due to their low operational and maintenance costs, a result of not requiring fuel for their operations.

Furthermore, in order to be a partner in the global pursuit of low carbon economies producing minimal amounts of GHG emissions, it is recommended that the Government provides tariff reductions and tax incentives for solar PV investors especially to those who are engaged in supplying solar PV systems for domestic consumers with mid and low electricity consumptions who will need a long time to recover the high initial cost of such systems.

Accordingly, a policy decision on low-carbon energy concepts, renewable energy, and energy efficiency strategies focussing on a sustainable energy based economy which would be environmentally friendly and effective for 20 -50 years will have to be made. Use of renewable energy has to be encouraged, any subsidies provided for fossil fuel imports have to be removed and strategies to bring in changes in the attitudes of the general public have to be introduced, all with a view to boost a zero carbon based society. Special attention has to be given to break the market monopoly of carbon based fuel. Lifestyle changes, technological developments, GHG emission reductions and carbon emission reductions should be promoted with specific timeframes and milestones in the move towards a low carbon society with the goal of achieving 'green growth'.

Low carbon economic policies introducing reduced tariffs on the use of clean energy will encourage private parties to invest in clean energy sources such as solar PV with a business model emphasis.

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REFLECTION ON THE THEORY AND PRACTICE OF INTEGRAL SUSTAINABLE DESIGN IN RURAL CONTEXT: A LITERATURE REVIEW

Susan Ang[1], Gayani Karunasena[1*], Lalith De Silva[2] and Sachie Gunatilake[2]

[1]School of Architecture & Built Environment, Deakin University Geelong Waterfront Campus, Australia

[2]Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Sustainability is often discussed with regard to urban development. However, the prevailing system of developing rural areas with poor communities and numerous critical problems associated with the same are hardly in line with the concept of sustainability. In order to achieve a true rural development, the rural built environment should be provided with sustainability principles which produce economically, socially and environmentally responsible designs and constructions. In addition, the so called sustainable design and construction should respect the existing individual life style, cultural views, values and systems of the rural communities. Considering the need for addressing the aforementioned facts, this study aims at understanding the need for an integrated framework for sustainable building design and construction in the rural context. Accordingly, the Integral Sustainable Design theory is used to identify the multiple perspectives that should be addressed in sustainable rural development. The study is based on a comprehensive literature review on the rural community requirements and how they are adequately fulfilled with the application of sustainability in reference to the Integral Sustainability Design theory. The research findings reveal that an integrated framework for sustainable building design and construction can address a diverse range of issues available in the community such as poverty, lack of education, lack of protection for women and children, lack of protection in natural disasters and unstable living conditions while eliminating the prevailing short-termism and fragmentation of development. The research outcomes will provide a holistic view of application of sustainability in rural development through rethinking, design, construction and operation.

Keywords:*Design and Construction; Integral Sustainability Design Theory; Rural Context; Sustainability.*

1. INTRODUCTION

The rural communities all over the world come across with many demographic, economic, social and environmental challenges due to the geographic isolation, decreased young population, increased aged population and negative environmental impacts (Nicholls, 2004). These issues are often interconnected and have become the main reason for slow or no physical development in rural areas. Regardless of the efforts of the local governments and NGOs (Non-Governmental Organizations), the rural communities often maintain a stubborn reluctant behaviour with regard to a considerable change in their lifestyles (Murdoch, 2000). In fact, the migration of young generation and educated adults to urban areas with many financial benefits and multi-cultural attractions resulted underdevelopment of rural areas due to loss of human capital (Green, 2014). In such circumstances, sustainability is a novel concept to the rural communities. Even though it receives a significant academic attention, introducing sustainable development into rural areas cannot be often seen in practice (Scott *et al.,* 2000).

Rural sustainability obtains an equal importance as urban sustainability as rural areas often contribute to national economy; basically, by agricultural means (Marsden, 2006). However, the approach of achieving rural sustainability should be different from the approach of urban sustainability as rural communities value their traditions and culture. In fact, the rural sustainability should follow a locally defined context rather than a

*Corresponding Author: E-mail - gayani.karunasena@deakin.edu.au

universal definition, nevertheless, should include livelihood, social participation, justice and equity (Scott *et al.,* 2000). The key aim of rural sustainable development is not just preserving for future yet making the community capable of achieving welfare for its people, self-developing, protecting cultural values and preserving natural resources for reproduction and long-term usage for its economic activities such as manufacturing, trades, crafts, agriculture, recreation, tourism and other important areas (Belyaeva *et al.,* 2016).

The prevailing rural development strategies all over the world hardly consider about sustainable principles. In most of the third world Asian countries, sustainability is not completely addressed even though it has been used in design and construction (Kishnani, 2012). The design and construction processes are often fragmented and only focused on implementation of short-term solutions. Not having a long term sustainable plan will lead the communities to diverse issues such as availability of energy, cost increments and high maintenance (Mainali *et al.,* 2014). Hence, understanding the sustainability concept is essential and especially in this case, the concept of rural sustainability should be well understood. The so called fragmented and short-term development can be eliminated by using an integrated approach which provides a methodological and systematic framework for design and construction process (Kishnani, 2012). Accordingly, the aim of this study is to understand the need for an integrated framework for sustainable building design and construction in the rural context. Thus, paper intends to explain a systematic way of achieving rural sustainable development via an integral sustainable design approach.

2. RESEARCH METHODOLOGY

This paper is a theoretical evaluation based on the findings of the "Building Ampara" project initiated by the iDiDe (Intercultural Dialogue Through Design) program of Deakin University. Deakin University's iDiDe delivered a global mobility study tour model with structured immersive learning that focused upon sustainable rural community development in the Eastern district of Ampara, Sri Lanka. It is a structured program offering intercultural immersive learning experiences which utilizes a multidisciplinary and integrated perspective in sustainable design, eco-tourism, cultural preservation, and rural community infrastructure development in the conceptualisation (feasibility and design) and project development for realisation of prototype buildings (Ang, 2017). According to the findings of this project, a new research direction is encountered to identify whether there is a need for an integrated framework for sustainable building design and construction in the rural context. Accordingly, the programme recommended Integral Sustainable Design (ISD) theory to be used in rural sustainable development as a future research direction. ISD is intellectual framework which simultaneously includes and excludes differences by performing cross-cultural comparison of human experience, systems and performance which can be effectively used in any discipline to demonstrate a holistic view of its particular context (Esbjorn-Hargens, 2010). This paper intends to explore the way of using ISD theory in rural sustainable development by conducting a thorough literature review regarding the theory and the rural community development. Based on the literature, this paper explains why ISD is suitable for rural sustainable design and construction, how it can be used and what kind of an arrangement of ISD should be introduced for successful achievement of true rural sustainability. Context analysis, intercultural dialogue, interpersonal communication and cross-cultural and multi-leveled collaboration alongside supervised participation in community engagement activities were used as research techniques when gaining hands-on experience through the iDiDe study program activities. Content analysis on theme based coding used for the mapping of findings for four quadrants of ISD.

3. INTEGRAL SUSTAINABLE DESIGN (ISD) THEORY

3.1. HISTORY AND APPLICATION OF ISD THEORY

Based on the Integral Theory introduced by Wilber (2000), DeKay and Bennett (2011) introduced Integral Sustainable Design (ISD) theory with the intention of providing a more holistic approach of sustainability appraisal in the built environment (Roetzel *et al.,* 2017). Wilber's theory is a philosophical approach which provides an outline to comprehend the intricacy of various contending theories, products and methods related to human knowledge (DeKay & Bennett, 2011). The key assumption of integral theory is that "everyone is right", at least partly (DeKay & Guzowski, 2006). In fact, the theory introduces an intellectual framework which simultaneously includes and excludes differences by performing cross-cultural comparison of human knowledge, experience and analysis. The main advantage of this theory is that it can be effectively used in any discipline to demonstrate a holistic view of the its particular context (Esbjorn-Hargens, 2010). In fact, it has been used in disciplines such as economics, art, medicine, law, religious studies, education, design and construction, and psychology. In particular, DeKay and Bennett (2011) discussed how this approach can be effectively applied with general sustainability design (Roetzel *et al.,* 2017). Following the integral theory, ISD consists of four main quadrants representing the multiple perspectives. Figure 1 demonstrates these four quadrants and their respective perspectives.

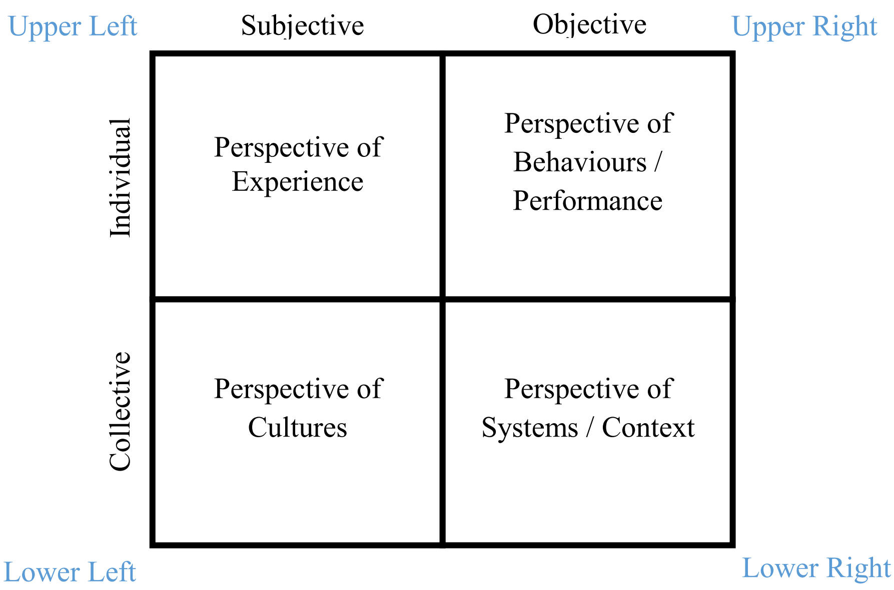

Figure 1: Four Quadrants of Integral Sustainable Design

Source: DeKay and Guzowski (2006); Roetzel et al. (2017)

According to Figure 1, the four quadrants represents; (1) perspective of experiences in which the main focus is on human senses, emotions, consciousness, feelings and experiences; (2) perspective of behaviours which focus on science, performance, mechanisms, measurements and calculations; (3) perspective of cultures in which the main focus is on mutual understanding, denotations, world views and symbolism; and (4) perspective of systems which focus on mapping, systems understanding, social and natural ecologies and contexts (DeKay & Guzowski, 2006; Roetzel *et al*., 2017; Roetzel *et al.,* 2015). In fact, these perspectives consider internal and external aspects of both individual and collective certainties of sustainable design development (Esbjorn-Hargens, 2010). The upper left quadrant signifies the subjective and individual aspects (experiences) whereas the lower left quadrant signifies the subjective and collective aspects (culture). On the other hand, upper right quadrant signifies individual and objective aspects whereas the lower right quadrant signifies collective and objective aspects. If further described, experiences represent “I” concept of ecological issues whereas cultures represent “we” concept. Similarly, the behaviours represent “it” concept of ecological issues whereas systems represent “its” concept (Roetzel *et al.,* 2017). Considering the aforementioned explanations, Roetzel *et al.* (2017) and Roetzel *et al.* (2015) put forward typical main questions that can be seen with regard to each quadrant. Table 1 provides a summary of these questions and the nature of each quadrant.

Table 1: Summary of ISD Quadrants

ISD Quadrant	Nature	Main Question
Upper left - Experiences	Qualitative	How does an individual experience nature through the building?
Upper right - Behaviours	Quantitative	How does the building perform?
Lower left – Cultures	Qualitative	What collective interpretation of nature does the building suggest?
Lower right- Systems	Quantitative	What is the nature of the relationships of the building with nature?

Source: Roetzel et al. (2017); Roetzel et al. (2015)

3.2. INTEGRAL SUSTAINABLE DESIGN APPROACH

ISD is a way of clarification of the sustainable design development with regard to the Integral Theory introduced by Wilber (2000) (Roetzel *et al.,* 2017). It basically provides a map of four quadrants which should be considered by the designers when they make a particular sustainable design (O'Brien & Hochachka, 2010; Roetzel *et al.,* 2017). In fact, it assists designers and practitioners to re-evaluate the scope, comprehensiveness and multidimensional facets of sustainability (DeKay & Guzowski, 2006). If further elaborated, the aim of ISD is to perform as a reminder that multiple perspectives have to be addressed when dealing with nature and adhering to sustainable development (Roetzel *et al.,* 2017). Moreover, the most concerning perspective will be decided by the most specific challenge faced by a designer. ISD not only provides four different perspectives to be considered yet it also explains these perspectives in four different levels (DeKay & Bennett, 2011). Therefore, each quadrant will have four levels and all together, there will be 16 different levels of perspectives to be considered when developing a sustainable design (Roetzel *et al.*, 2017).

According to Roetzel *et al.* (2017)'s explanation regarding the aforementioned four levels, level 1 is a traditional comprehension of nature which concentrates on the ways of using local forces within the site perimeter or how to be protected from them. Passive solar design and dialect architecture are two examples for this level of consideration. Level 2 represents the modern comprehension of nature where the nature is considered and utilized as a resource. Since, there is a limited amount of non-renewable resources, the focus in this level is to optimize the available resource usage such as non-renewable energy. Low energy buildings are an example for this level. Level 3 is the post-modern comprehension of nature which focus on protecting nature with regard to its magnitude and complexity in ecosystems. The main focus in this level is to interact the diverse elements of the ecosystem with each other and maintain a significant balance between them. Green buildings could be a proper example for this level as it uses various parameters to protect nature while maintaining an adequate balance between them. Level 4 represents the future beyond the post-modern comprehension of nature which not only focus on one ecosystem yet consider multiple ecologies and living systems. This level demonstrates more dynamic patterns than linear relationships. Figure 2 demonstrates the way of aforementioned four levels are associated with the four quadrants of ISD.

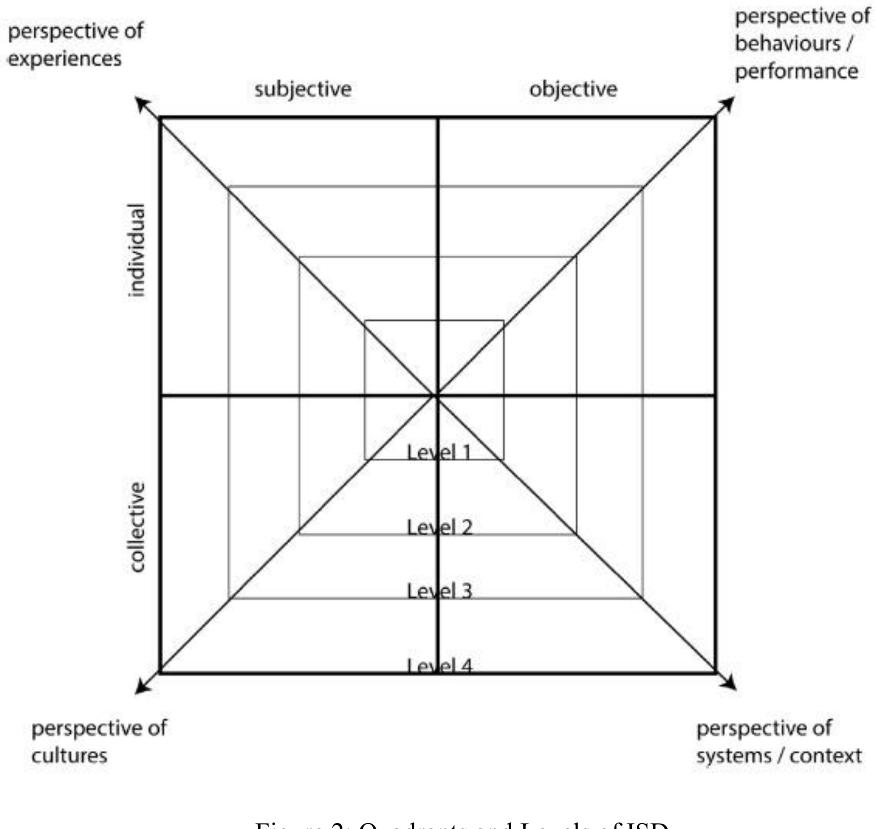

Figure 2: Quadrants and Levels of ISD

Source: Roetzel *et al.* (2017)

4. RURAL BUILT ENVIRONMENT

A rural area was initially defined as an area with less than 2000 residents, yet the latest definition established by the Organization for Economic Cooperation and Development (OECD) describes a rural area as an area with less than 150 people per km^2 of population density (European Commission, 2017). In many Asian developing countries such as Sri Lanka, the rural areas are often defined geographically; that the areas outside the borders of local administrative authorities such as urban councils and municipal councils are the rural areas (Wickramasinghe, 2010). These authorities are set as per the availability of developed infrastructure on particular areas which define the urban living and established by the Urban Development Authority (UDA). The local governments and private organizations all over the world are continuously engaged in rural development with the initial idea of providing them with basic common amenities (Kleemeier, 2000; Murdoch, 2000) yet hardly concerned of addressing sustainability. In particular, one of the most common issues of countries with civil wars and social conflicts is the huge rise in community displacement and infrastructure destruction; especially in rural areas (Seneviratne *et al.,* 2015). This leads the local governments to reconstruction with limited time, finance and social resources, thus the focus is mainly on providing basic facilities. Hence, long term sustainable constructions cannot be often seen in such rural areas.

The traditional attitudes, believes and living styles of rural communities often obstruct the systematic development of rural areas (Murdoch, 2000). Moreover, the fear of losing their assets and living conditions often generate local reluctance to rural development. Therefore, an effective way has to be introduced which simultaneously address the physical development, preservation of prevailing life styles and avoidance of common issues which barricade the upgrading of rural areas. In fact, there are much to do with regard to rural development and poverty elimination all over the world regardless of the current initiatives taken by different authorities (The World Bank, 2015).

4.1. COMMON RURAL ISSUES TO BE CONSIDERED IN RURAL DEVELOPMENT

Rural communities are often hit by similar issues, despite of the geography, culture and population (Falk, 2001). Poverty is one such issue. According to the International Monetary Fund, there are many causes of rural poverty such as yet not limited to attitudes on gender, cultural beliefs, adverse weather and climate, market conditions and public policies (Khan, 2001). The physical and environmental conditions of rural areas are often suitable for agriculture (Tassinari et al., 2008), thus, most of the rural inhabitants all over the world are cultivators (Khan, 2001). Nevertheless, there is a significant number of non-cultivators who work on other fields such as miners, craftsmen, carpenters, masons and unskilled labourers who work for daily and sessional demands (Khan, 2001). Most of these occupations demand physical fitness and a supportive climate which are highly subjective by nature, thus, hardly provide a job security and a regular income. The uncertainties of income, unaccommodating economic policies which exclude the rural communities from national development procedures, corrupted local politics and public bureaucracies and negative civil conditions such as civil wars, riots and conflicts often drag rural inhabitants towards poverty (Khan, 2001).

Health issues are another common problem that can be often seen in rural communities (University of Minnesota Libraries Publishing, 2010). Lack of medical facilities, hospitals and medical centres, medical professionals, emergency transportation and equipment obstruct providing a high-quality service to the general public in rural areas (National Rural Health Association, 2012; Nicholls, 2004). On the other hand, the elderly population is considerably high in comparison to young and middle-aged population due to migration to urban areas looking for diverse job opportunities (Center for Rural Affairs, 2009). It adds up an additional burden to the prevailing health care problems since looking after the health requirements of elderly people is considerably expensive (University of Minnesota Libraries Publishing, 2010). Moreover, the geographic isolation of rural areas barricades providing effective medical services and other facilities (Black et al., 2000). Most of the rural areas are being rural for a long time due to their isolated location and lack of facilities. Professionals of various disciplines are reluctant to work in these areas due to the lack of facilities, thus, providing a high-quality service in relevant fields is very difficult and hardly acquire a development (Center for Rural Policy and Development, 2009). In fact, the voice of rural people is hardly reach the ears of political parties and governing bodies (Khan, 2001).

Work force migrating to urban areas is another issue in rural areas as it will lower the local labour availability (Green, 2014). In particular, the labour market will be affected negatively with reduced return on human capital investment, unemployment and the workers with same educational status in urban areas will earn more compared to local workers (Falk, 2001; Green, 2014). It will again create the necessity of settling in urban areas leaving the rural communities. Lack of education is another critical issue which has become a root cause for a number of issues. There are relatively limited number of schools in rural areas and the student count is relatively low (Center for Rural Policy and Development, 2009). Moreover, the facilities, school teachers, required level of education, diverse educational opportunities are not adequate in rural areas. Local students either enrol in urban schools with much facilities or leave school early due to the extreme poverty. On the other hand, rural schools are not capable of providing a wide range of course offerings thus, creating new job opportunities within rural community is hard and has not been given much attention (Green, 2014).

Lack of protection to women and children can be often seen in rural areas. Sexual abuse and domestic violence is relatively high in rural areas and human rights are not well understood or known by the female population of rural areas (Campo & Tayton, 2015; United Nations, 2007). Legal implications, social and legal services with regard to domestic violence in rural areas are not well established in rural areas as they are in urban areas (Campo & Tayton, 2015). Women hardly engage in family decision making especially about their children and family planning. When consider the children, lack of health care, lack of education, child workers and malnutrition can be often seen (Arloc, 1992). Women are not involved in financial control and leadership. The majority of them are not independent and employed due to lack of education, training and skills. Adverse weather and extreme climate is another issue encountered by rural people (Khan, 2001). Since agriculture is one of the main sources of income, adverse weather will damage their crops and even dwellings, resulting financial losses. This will ultimately diminish the economic growth of rural areas. On the other hand, most of the rural areas all over the world are often affected by civil wars, riots and conflicts which create a huge impact on the local economy as well as the social life of rural people (Seneviratne et al., 2015). Due to such circumstances, rural development is highly difficult and require a lot of time.

4.2. WHY SUSTAINABLE DESIGN AND CONSTRUCTION IS REQUIRED IN RURAL AREAS

Sustainable development in rural areas is not just carefully utilizing available resources and preserving them for future generations. It is now a broader concept which can be defined as "*a stable socio-economic development of rural areas, volume increasing of agricultural output, improvement of agricultural effectiveness, achievement of full-employment of rural population and increase in their level of living, rational land use*" (Belyaeva et al., 2016, p.6890). As per the aforementioned definition, rural sustainability should be achieved considering social, environmental and economic aspects of the area. If further described, the sustainable policies related to rural built environment should hold the environmental responsibility, economic profitability and social awareness (Ali & Nsairat, 2009). The effort to achieve rural sustainability will obviously be long term with the involvement of numerous industries and cover a wider community. There are several key objectives of rural sustainable development; (1) to preserve natural resources while using them effectively in long term economic activities such as tourism, agriculture, recreation, crafts and other trades, (2) to provide standard and high-quality living condition for rural community assuring community development and welfare, (3) to enable self-development, and (4) to protect cultural values and behaviour (Belyaeva *et.al.,* 2016). Section 3.1 clearly indicate the current social, economic and environmental issues of rural areas which should be promptly addressed via rural sustainable development. In fact, policies should be made to increase the agricultural productivity and to provide a fair share in the national economy (Global Monitoring Report, 2013). Non-agricultural occupations should be encouraged and introduced to rural areas to maintain a stable economy and a market. On the other hand, infrastructure, health care and common amenities should be adequately provided to rural areas to increase their contribution to the national economy (United Nations, 2015). Since there are many areas to be addressed, it is effective to adopt an effective framework to successfully achieve true rural sustainability. When consider the key objectives of rural sustainability and prevailing issues in rural areas, ISD theory can be used to achieve a holistic view regarding this matter and accordingly develop the design and construction of rural buildings, infrastructure and common amenities.

5. ISD FOR RURAL SUSTAINABILITY DEVELOPMENT

ISD is highly effective in providing a holistic approach to sustainable development (Roetzel *et al.,* 2017). It considers experiences, behaviour, culture and systems in designing and construction of rural built environment. As identified through iDiDe study tours, poor economies of scale, low investment levels resulting from poor financial services, inappropriate or limited technology, fragmented landholding, inequality of income and disparities in opportunities available for secondary education (especially for girls), gender equality, clean water & sanitation are the most evident concerns in most of the rural areas of Ampara. The aforementioned information regarding the rural communities emerge several critical questions for which the answers must be found in order to achieve true rural sustainability. Accordingly referring to IDF theory, following four key questions are formulated to determine the need for an integrated framework for sustainable building design and construction in the rural context as illustrated at Figure 3.

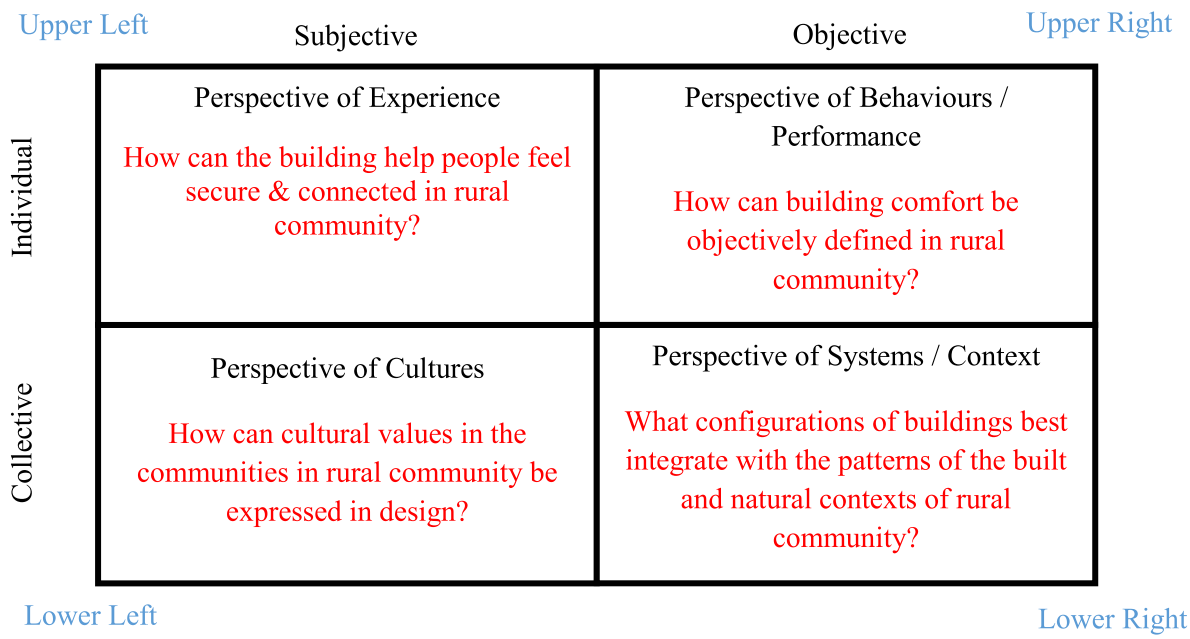

Figure 3: Key research questions formulated based on ISD theory

Source: Roetzel *et al*. (2017)

Following sections discuss how formulated key research questions can effectively address the need for an integrated framework for sustainable building design and construction in the rural context based on comprehensive literature review findings.

5.1. How can the Building Help People Feel Secure & Connected in Rural Community?

A house is a more personal object thus should be designed according to the personal requirements. In fact, the individual experiences should be taken into consideration when designing houses for rural people. Moreover, there needs will be different from each other, thus, require adding personal features to designs based on their thoughts, feelings and experiences (Roetzel et al., 2017). A mutual understanding between the designer and the resident is necessary and the houses should symbolize the resident's lifestyle. As per the findings of Roetzel et al. (2017) and Roetzel et al. (2015), these new house designs should allow the residents to experience and interpret nature through the house while providing comfort and protection. In particular, the issues such as lack of health care and protection for women and children should be addressed in these designs.

5.2. How can Building Comfort be Objectively Defined in Rural Community?

This question should be addresses quantitatively as it concerns the methods used for design and construction of buildings in rural areas. Based on DeKay and Guzowski (2006)'s ISD theory, perspective of behaviours and perspective of systems should be considered in deciding the methods. Following the findings of Roetzel et al. (2017) and Roetzel et al. (2015), scientific approaches, performances and mechanisms should be used for design and construction with accurate measurements and calculations. On the other hand, these designs should follow a systematic approach which understand the value of social and natural ecologies. Moreover, the designs should be done considering and defining the performance of the building and its relationship with nature (Roetzel et al., 2017). The rural issues such as poverty and the harm that can be done by adverse weather can be effectively reduced via this kind of approach.

5.3. *What Configurations of Buildings Best Integrate with the Patterns of the Built and Natural Contexts of Rural Community?*

In terms of perspective of systems, mapping, systems understanding and social and natural ecological contexts should be used. Accordingly, the types of material resources should be measured by using science and technology and properly calculated to define the amount of usage which ensures the sustainability. Moreover, the resource areas should be accurately mapped and their natural content should be well understood. Most importantly, the usage of natural resources should not disturb the ecological systems. On the other hand, the rural issues such as young population migrating to urban areas due to unemployment and lack of education with regard to diverse disciplines can be addressed via this kind of integrated approach. Further, unemployment, poverty, lack of diverse education can be eliminated effectively if the skills of local community can be utilized and improved. On the other hand, using local skill will assist in producing an area specific designs with real requirements. The active participation of local community in rural development will enhance the local facilities as well as the local life quality. Having sufficient employment will reduce a number of problems such as domestic violence, poverty, lack of health facilities, young people migrating to urban areas and lack of education.

5.4. *How can Cultural Values in the Communities in Rural Community be Expressed in Design?*

The type of buildings required by the rural community is highly depended on the individual needs and cultural values. The buildings must fulfil the requirements of the inhabitants while protecting and emerging their cultural values. According to the findings of DeKay and Guzowski (2006), Roetzel et al. (2017) and Roetzel et al. (2015), this question should be addressed with a qualitative approach which considers human experiences, emotions, feelings and senses while ensuring mutual understanding of social and natural ecologies, symbolism, denotations and public views. In fact, it is crucial to identify the ways of making rural people experience the nature and culture through the new constructions. In addition, these new designs and constructions collectively should provide an interpretation of nature (Roetzel et al., 2015). Further, the knowledge of local people regarding their inheritance, cultural values and customs can be used for more innovative and unique designs which go along with nature and ensure sustainability.

6. Conclusions and Recommendations

This paper is a theoretical analysis of one of the future research directions introduced by the iDiDE programme conducted by Deakin University. Accordingly, the need (why, how and what) for an integrated framework for sustainable building design and construction in the rural context is hypothetically evaluated. ISD theory is introduced as the integrated framework for rural sustainable development since it provides a holistic view of sustainable design and construction. The four quadrants of ISD address both qualitative and quantitative perspectives of sustainability by considering the individual and collective output. In addition, the four levels of each quadrant provide a scale at which the nature should be understood. The study identified several common issues faced by rural communities all over the world such as poverty, lack of health facilities, lack of education, unemployment, young generation migrating to urban areas, adverse weather and extreme climate, destruction caused by civil wars and conflicts and lack of protection for women and children. In order to achieve true rural sustainability, these issues should be socially, economically and environmentally addressed for which ISD can be effectively used. Four questions are emerged with regard to rural sustainability which have been explained using ISD theory. Accordingly, the study highly recommends the use of ISD or an equivalent theory for understanding and achieving rural sustainable development in the fields of design and construction. However, without conducting a field study it is difficult to carry out an in-depth analysis of all of these questions. In particular, addressing sustainability with levels of ISD is not effective in a theoretical analysis as there is no case study to be analysed. As the way forward, Deakin University, Australia collaboration with University of Moratuwa, Sri Lanka is conducting, research project on how ISD theory can be applied to improve rural community building in Amapara, Sri Lanka. Eventually, outcomes of this case study will be helped to establish the need for an integrated framework for sustainable building design and construction in the rural context.

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REVIEW OF IMPACT OF JUDICIAL INTERFERENCE TO ENHANCE CONSTRUCTION ARBITRATION IN SRI LANKA

D.R. Senarathna and Mahesh Abeynayake*

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

The basic characteristics of built environment activities are complexity and disputability in its own nature. This complexity drives most of the construction projects and contracts towards disputes between parties. Construction contracts in the industry are more complex than all other type of business contracts by its nature. This complexity itself has paved the path for disagreements between parties of such contracts. Although disputes are common in Sri Lankan construction industry as elsewhere in the world, dispute resolution mechanisms are not admired in Sri Lanka. The litigation process is the traditional mode of dispute resolution, drawbacks of litigation process have opened up the 'Alternative Dispute Resolution' (ADR) methods. Literature based on the process of Arbitration in Sri Lanka and other countries reveal that using Arbitration as an alternative method to the court system will be more beneficial than court litigation. It is evident that there would be a high possibility to ensure the efficacy of the process of Arbitration by minimising the interference of the judiciary. At present Arbitration as an ADR method does not efficiently resolve the disputes.

This research examines the usage of Arbitration as an ADR method to resolve the construction disputes instead of traditional litigation. However, the current arbitration method and its practice hinders the advantages by irregular judicial interferences which prolong its efficiency. The aim of this research is to recommend effective amendments for current Arbitration practice in Sri Lanka by reviewing the impact of judicial interference. This research proposes a well-planned Arbitration method which can avoid pitfalls in the current legal regime of the Arbitration practice in Sri Lanka. Further it seeks to suggest positive amendments for the Act to avoid loopholes and minimise the challenging grounds of arbitral awards.

Keywords:*Arbitration; Construction Industry; Dispute Resolution; Judicial Interference.*

1. INTRODUCTION

Construction projects are complex in its own nature as well as its performance. This complexity drives most of the construction projects and contracts to disputes between parties. (Saleem, 2016) Disputes might arise at any scale of a construction and they tend to be more intensive and multifaced in comparison with the ordinary civil disputes. Mustill and Boyed (1989) states, before introducing the Dispute Resolution Methods to the construction field, most of the disputes were solved by mutual agreement between parties or, under court litigation. However, as a result of many technological issues and the complexity of the construction projects. The disputes and their resolution have become a primary focus in the strategic plans of businesses (Kleiner and Mose, 2016). Dart, recommends the best solution is to avoid disputes even though disputes may arise (1994 cited Latham 1994).

Those mutual agreements between disputed parties were not so beneficial and, court litigation also couldn't answer the complexity of those projects as lawyers and judges rarely have the knowledge of the technical aspects of the projects. Alternative Dispute Resolution Methods were introduced in order to answer the pitfalls occurred in the use of traditional litigation. In the case of State of Kerala Vs. Joseph Auchilose (1990), court states that time consuming, interminable, complex and expensive court procedure impelled the jurists to search

*Corresponding Author: E-mail - abey92@hotmail.com

for an alternative and more effective and speedy resolution method. When there's a dispute relating to a business project, litigation sometimes does not provide an expeditious an effective solution. As a result, Alternative Dispute Resolution Methods (ADR) viz. arbitration, mediation, conciliation and negotiation have been developed. They ensure the confidentiality, understanding among the parties, saving cost and consuming technology.

Arbitration does not function completely apart from the judicial system. Justice Wimalachandra (2007) states the court intervention in arbitration can't be refused and court assistance in the process may be sought in many cases like appointment of arbitrator, termination of arbitrator's mandate and removal of arbitrators, grounds for challenge, competence of arbitral tribunal, interim measures of proceedings, obtaining summons, refusal or failure to Attend before Arbitral Tribunal, Application for filling and enforcement of award , remission to arbitral tribunal , appeals and enforcement which depend on the assistance of the courts with regard to Sri Lankan law of arbitration. (Kanag-Isvaran, 2011) There's no arbitration without the assistance and the guidance of the judiciary. What need to be done is moderating the way of this assistance and reducing the duration of time which results as a consequence of the intervention of the judiciary. In order to achieve this, the recommendation is to enhance the way of court intervention to expedite the process and encourage the judiciary to make their decisions regarding the arbitration within a short duration or during the construction period itself, if possible. The Hypothesis of this research is that there is more impact on judicial interference for Arbitration process.

Aim of this research is to review the impact of judicial interference to arbitration method as an effective ADR method to resolve construction disputes in the construction industry in Sri Lanka. It aims to investigate how to improve the arbitration process by encouraging to minimize the judicial interference and allowing process to stand as an independent ADR method. In order to fulfil above aim, objectives of the research would be to;

- Review the features of Arbitration and its conflicting areas in comparison to litigation.
- Identify the impact of judicial interference to enhance the Sri Lankan arbitration method and its practice.
- Review progressive efforts taken by other jurisdictions to enhance the efficiency of Arbitration in the construction industry.
- Make recommendations to enhance the impact of judicial interferences for arbitral awards to improve the efficiency of Arbitration method.

This research is limited to analysing the Arbitration in the construction industry in Sri Lanka based on the developed other jurisdictional efforts which have been taken to enhance the effectively of the Arbitration. And basically, the data has are been collected is limited to the knowledge of professionals who are actively engaged in the Arbitral dispute settlements and also the other stakeholders like engineers, consultants and constructors.

2. LITERATURE REVIEW

ADR methods are recognized as an alternative to the litigation method. Lord Denning in his famous judgment in the Court of Appeal in *Dawnays Ltd Vs Minter Ltd* case, held that "There must be cash flow in the building trades. It is the very lifeblood of the enterprise ". And "One of the greatest threats to cash flow is the incidences of disputes, resolving them by litigation is frequently lengthy and expensive. Arbitration in the construction industry is often as bad or worst "([1971] 1 B.L.R. 1205). Justice Wimalachandra has defined ADR method as any form or procedure, whether formal or informal, whereby parties could resolve their disputes instead of litigation before courts of law (Wimalachandra, 2007).

Arbitration was born in England as an Alternative Dispute Resolution. Earlier it was an alternative distinctive from litigation. The US has developed a special Dispute Board concept, involving the appointment of a panel of independent persons who maintain the affairs of project throughout its life. If a dispute arises this panel is called in to make recommendations rather than a decision on the dispute. These recommendations are not binding but would be accepted by the parties. This system has been credited for its nature of saving many hundreds of millions of dollars for project participants. There is a wide general acceptance for the quick and effective methods for the resolution of disputes in business projects. Dispute Adjudication Boards which render decisions that are temporarily binding but pending further procedure have become the standard model without possessing an insight knowledge of formal and conventional way of dispute resolution it is futile understand the alternative ways.

In this research, legal instruments can be widely useful to support progressive enhancements of the Sri Lankan Arbitration. Mainly the Arbitration Act of Sri Lanka No. 11 of 1995 is the basic instrument which was analysed and evaluated based on the above legal instruments. The UNCITRAL model law on International Commercial Arbitration, is the core legal framework which has been implemented by most of the countries all over the world and each and every country which is signatory to this model law is obliged to amend the national law of Arbitration according to this. Proceedings of Construction Industry Arbitration Council 2015 India- With a view to providing an institutional mechanism for resolution of construction and infrastructure related disputes, the Construction Industry Development Council, India (CIDC) in cooperation with the Singapore International Arbitration Centre (SIAC) has set up an Arbitration Centre in India called the Construction Industry Arbitration Council (CIAC). Further, in England the Technology and Construction Court Guide Second Edition Issued 3rd October 2005, third revision with effect from 3 March 2014.

From the interviews with prominent professionals in the construction industry and literature survey it was understood that, there are four ADR methods-Negotiation, Mediation, Adjudication and Arbitration-mainly practicing in Sri Lankan construction industry. The practicing of ADR methods can be indicated as a stair step way (Cheung, 1999; O'reilly and Mawdesley, 1994). It mentioned in Figure 1.

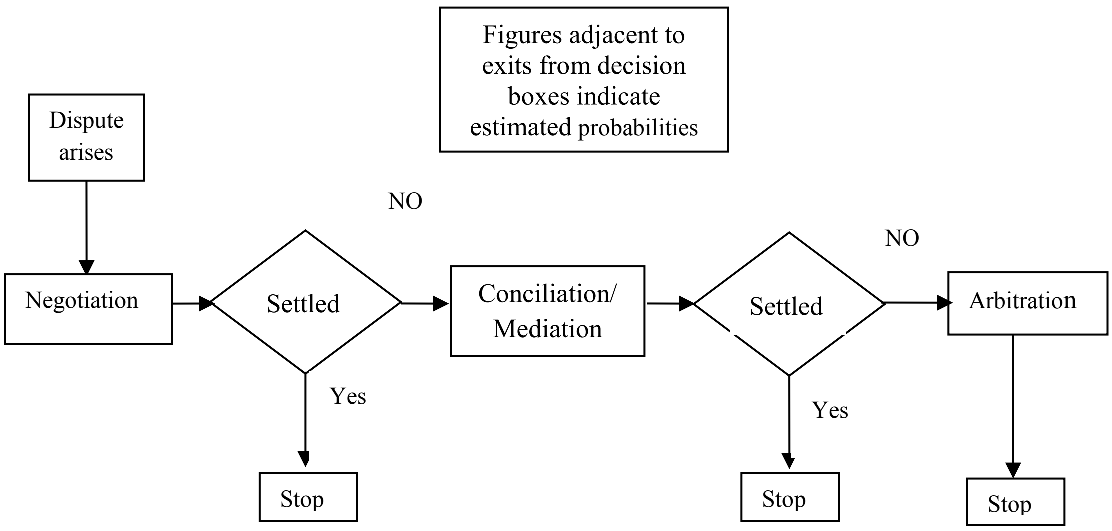

Figure 1: Probabilistic Network or Flow Diagram of ADR Application

Source: O'reilly and Mawdesley (1994)

3. ARBITRATION AS AN ALTERNATIVE DISPUTE RESOLUTION METHOD

Arbitration is considered as a "businessman's" method of resolving disputes and a process much like a trial without a jury (Neale and Kleiner, 2001). The construction industry uses arbitration as its principal final mode of dispute resolution (Sims et al., 2013). It can be considered as a suitable mechanism for many construction industry disputes, but not for all (Goonarathna 2007; Sims et al. 2013). "Despite its decline, arbitration is still the preferred method of final dispute resolution in the construction industry" (Sims et al. 2013).

The Arbitration Act of Sri Lanka No. 11 of 1995 provides for a legislative framework for the effective conduct of arbitration proceedings as well as the most practicable or methodical mechanism for the enforcement of arbitral awards thereby making arbitration a viable and expeditious alternative to litigation for the resolution of commercial disputes. This act describes the rules when resolving a dispute using arbitration. Sri Lanka was the first country in South Asia to enact an arbitration law, by way of the Arbitration Act. The Arbitration Act of Sri Lanka No 11 of 1995 stated how to resolve disputes arise in any industry. The Act provides that an arbitration agreement shall be in writing.

3.1. PERSPECTIVE ON ARBITRATION IN THE CONSTRUCTION INDUSTRY OF SRI LANKA

Until the enactment of the Arbitration in 1995, the Arbitration Law practiced in Sri Lanka was based primarily on three statutes ; Arbitration Ordinance No. 15 of 1856, Civil Procedure Code of No. 2 of 1889, Reciprocal Enforcement of Foreign Judgements Ordinance No. 41 of 1921.The Arbitration Act of 1995 was the first Arbitration law in South Asia to be based on the United Nations Commission on International Trade Law (UNCITRAL) Model Law on International Commercial Arbitration and inspired by the then draft Swedish Arbitration Act. The Parliament of Sri Lanka has enacted statutes to implement the ADR methods. Commercial arbitration proceedings are governed by the Arbitration Act No.11 of 1995. Mediation practices are regulated by Mediation Board Act No. 72 of 1988 and its amendments. Further the Commercial Mediation Centre of Sri Lanka Act No. 44 of 2000, Mediation Boards (Special kind of disputes) Act No. 21 of 2003 and its recent amendment Act No 04 of 2011 regulate the given issue.

According to the aforesaid legal provisions the original civil jurisdiction which heavily affects the contractual matters in the business industry are vested on District Courts except where the cause of action has arisen out of some commercial transactions of more than five million rupees. The jurisdiction vested in the Commercial High Court established by High Court of Provinces (Special Provisions) Act No. 10 of 1996. According to the procedural law of Sri Lanka the appellate jurisdiction of commercial disputes is vested on Civil Appellate High Courts, Court of Appeal and the Supreme Court. The judicial system is one form of dispute resolution that is available to the parties of dispute. However, in Sri Lanka there is a tendency to assume that litigation is the normal dispute resolution method and there is a concern that people turn too quickly to the courts with their disputes (Wimalachandra, 2007).

The court intervention in arbitration can't be refused and court assistance in the process may be sought in many cases like appointment of arbitrator, termination of arbitrator's mandate and removal of arbitrators, grounds for challenge, competence of arbitral tribunal, interim measures of proceedings, obtaining summons, refusal or failure to Attend before Arbitral Tribunal, Application for filling and enforcement of award , remission to arbitral tribunal , appeals and enforcement which depend on the assistance of the courts with regard to Sri Lankan law of arbitration. (Kanag-Isvaran, 2011) There's no arbitration without the assistance and the guidance of the judiciary. What need to be done is moderating the way of this assistance and reducing the duration of time which results as a consequence of the intervention of the judiciary. In order to achieve this, the recommendation is to enhance the way of court intervention to expedite the process and encourage the judiciary to make their decisions regarding the arbitration within a short duration or during the construction period itself, if possible.

Further there are some cases which were decided by Superior Courts of Sri Lanka and now those have become a part of arbitration law as a judicial precedent. As an example, Southern group civil construction private limited vs. Ocean Lanka private limited case discussed the grounds for setting aside an arbitral award and the time limitation for challenge the arbitrator's award. In State Timber Corporation vs. Moiz Goh (pvt) Ltd case, court held that the district court has no jurisdiction to enter in to the arbitration proceeding. In Sri Lanka the arbitration process is conducted in two ways; Ad-hoc arbitration is conducted when the parties decide on their own procedure to be adopted in the conduct of the arbitration proceedings. It is observed that most domestic construction contracts are conducted on Ad-hoc procedures (De Zylva, 2006). Arbitral institutions under its own rules of arbitral procedure conduct the Institutional arbitration. It provides the framework of rules and such other facilities for entire proceeding. There are three main arbitration institutions in Sri Lanka called as 'International Chamber of Commerce', 'Institute for the Development of Commercial Law and Practice (ICLP)' and 'Sri Lanka National Arbitration Center' which facilitates construction arbitration.

The Arbitration Act in itself does not lay down any rules of Arbitration. But deals with the composition of the arbitral tribunal, the jurisdiction of the arbitral tribunal, the conduct of arbitral proceedings, awards, enforcement of awards, recognition and enforcement of foreign Arbitral awards and grounds for refusing or enforcement of awards by sections of the Arbitration Act. Due to the absence of strict rules of Arbitration provided in the Act, the parties are free to choose the rules under which their arbitration should be conducted. According to the section 32 (1) (a) of the arbitration Act, it expressly states the grounds on which such an order can be set aside.

Another drawback in current Arbitration process is unenforceability of arbitral awards. Number of cases are pending in courts due to this reason. Manathunga and Seneviratne (2016) illustrates the categorization of arbitral cases based on the ground for rejection of the arbitral awards as follows;

Table 1: Grounds Leading to Unenforceability of Arbitral Awards

Ground for setting aside or refusal to enforcement	Total for the category
Non-adherence to enforcement procedure	17
Violation of due process	3
Excess of authority	1
Irregular constitution of the arbitral tribunal or irregularity of arbitral procedure	1
Award conflicts with the Public Policy	8

The research illustrates that majority of unenforceable arbitral awards are belonging to non-adherence to enforcement procedure while public policy grounds lie next it. Further they have aimed to find out the reasons for the most common ground leading to the unenforceability of arbitral awards and resulted as follows;

Table 2: Reasons for non-adherence

Reasons for non-adherence	Number of Cases
Performance defects of legal counsel	9
Not understanding the requirements of Section.31of the Arbitration Act	1
Failure of the company strategy on the award	1
Performance defects of the officer in charge of the case	3
Relevant officers are not knowing the actual reason	2

Their findings indicate that majority of unenforced arbitral awards belonging to "non-adherence to enforcement procedure" become unenforceable due to the performance defects of the legal counsel. Performance defects of the relevant officer in charge (to follow up the case) are responsible subsequently. Also least amount of arbitral awards become unenforceable due to failure of the company strategy on the arbitral award and lack of understanding of the requirements of section 31 of the Act.

Based on the literature survey done for the purpose of this research it can be identified that most of the leading arbitrators are of the opinion that arbitration was becoming almost court litigation. In this light, the research explores the effectiveness of Arbitration as an alternative method to resolve construction-based disputes and the necessity to reduce the duration of time by minimizing the court intervention in many stages of Arbitration.

4. RESEARCH METHODOLOGY

To accomplish the above objectives, it was aimed to analyse the literature based review based on commercial Arbitration. The literature review based on this research had done to figure out what are the effective steps which could enhance the purpose of Arbitration method as an alternative to court litigation. The literature review focused about the progressive Arbitration modules which has been taken in other jurisdictions like India, UK and USA. In case the literature review based on this research was only done including other related articles on formal Arbitration process not about the commercial Arbitration and its applicability of recent trends.

5. FINDINGS

The main objective of entering into the arbitration method instead of Court proceeding is to settle the dispute more expeditiously. The Arbitration Act No. 11 of 1995 of Sri Lanka itself facilitate this by ensuring that Courts shall not interfere in arbitration proceedings unless otherwise required by the said Arbitration Act. It clearly states the circumstances where Courts intervene in the Arbitration proceedings. This Act was drafted according to the UNCITRAL Model Laws on Commercial Arbitration and the Article 5 of the Model Law under the heading of "Extent of Court Intervention" states that, "In matters governed by this Law, no court shall intervene except where so provided in this Law".

The section 5 of the Arbitration Act of Sri Lanka also highlights the above fact under the heading of "Jurisdiction", as follows,

"Where a party to an arbitration agreement institutes legal proceeding in a court against another party to such agreement in respect of a matter agreed to be submitted for arbitration under such agreement, the Court shall have no jurisdiction to hear and determine such matter if the other party objects to the court exercising jurisdiction in respect of such matter".

This is generally known as severability where court cannot interfere when there is an agreement to arbitrate. The major point which has to be specifically understood here is that all of these interventions by the Courts or other Authorities are treated as the level of Assistance and Supervision. Model Law itself do not grant a solely power for Courts to engage in the arbitration proceedings and it ensures the independency of the Arbitration. This kind of assistance from the Court side is a necessary to functioning the Arbitration without any destructions. The minimal interference of the judiciary is a fundamental requirement that it can be more helpful to ensure the efficiency of the arbitration. The principle of this minimal interference of Courts in the arbitration was highly encouraged by the Judgment of McDermott International Inc. vs Burn Standard Co. Ltd (2006) and it was based on the Arbitration and Conciliation Act of 1996 of India. In parallel to the said amendments, article by Rohith, Shishir and Mayank (2016), Dispute Resolution in India in the light of the New Arbitration Act 2015, highlights about the significant increment in the role of domestic and international trade in economic development of India. Further, Considerable increment of the commercial disputes accompanied with that economic growth. Further, in Arbitration Act of 1996 in India was enacted to achieve the twin goals of inexpensive and quick resolution of the disputes.

In the case of Mahawaduge Priyanga Lakshitha Prasad Perera Vs. China National Technical Imports & Export Corporation, under the judgement High Court judge mentioned as follows;

"In this case a preliminary objection was raised to the maintainability of the application on the grounds that the petitioner has no right in law to invoke the jurisdiction of High Court in terms of Section 11 of the Arbitration Act subsequent to both parties inviting the tribunal to decide its jurisdiction and the tribunal ruling that it had no jurisdiction".

According to this judgment delivered by the Commercial High Court under the law of Sri Lanka, any positive decision of the tribunal related to its jurisdiction is subject to challenge only following the making of the award in an application for setting aside an award under the Section 32(1). In the foresaid case commercial high court by analyzing section 11 indicated to which extent can a arbitral tribunal may deal with or dispose of a challenge to its jurisdiction and under this he recognized the preliminary question and decided that it lacks jurisdiction as a negative ruling and also postpone for decision on the award on merits and decide that it lacks jurisdiction also as a negative jurisdiction on ruling, further this case ensures that any party cannot apply to the High Court seeking guidance as to the jurisdiction of the tribunal when the tribunal makes a negative ruling upon invitation of both parties, unless Section 11 or any other section statutorily recognizes that such remedy is available in the Arbitration Act. This has to be argued that the legislation itself secured the powers of the Arbitration Tribunals by determining to reduce unnecessary delays in Arbitration.

Furthermore, in the UK Technology Construction Court have been introduced to investigate technically complex issues in order to have expeditious dispute resolution system consisting experts such as engineers, architects, surveyors, accountants, and other specialized advisors etc.

6. RECOMMENDATIONS

Constriction organizations could maintain a Dispute Management System (DMS) consisting internal and external experts in the field of built environment for minimise judicial interference. Rather than rushing towards litigation or arbitration companies should exercise every possible effort to arbitrate disputes with stakeholders. Parties have to forward their dispute to an independent arbitration institute specialised in construction sector. Institute should have powers to settle the dispute without any court interference. Currently we have only two arbitration centres, ICLP and National Arbitration Centre.

Technology and Construction Courts (TCC) could be introduced in Sri Lanka as the final resort if the matter could not be settled by way of arbitration. The TCC should deal primarily with litigation of disputes arising in the field of technology and construction. If the matter is not settled in the previous levels parties could forward it to the Commercial High Court. However, Government has to make necessary amendments to the law to achieve this level. In addition, government has to take steps to minimise the court interference in arbitration pertaining to business matters and encourage Judges to decide arbitration matters at earliest.

Arbitration Act should be amended as follows:

Amendment to section 8 - where the Court passes an order for any interim measure before the commencement of arbitral proceedings, the arbitral proceedings shall be commenced within a period of 90 days from the date of such order. If further provides that once the arbitral tribunal is constituted, the Court shall not entertain and application for interim measure unless it finds circumstances that may under the remedy provides under section 17 inefficacious. Thus, it restricts the tendency to approach courts for seeking interim relief.

Amendment to section 17- the arbitral tribunal shall have to grant all kinds of interim measures which the Court is empowered to grant under section 9 of the Act. Such interim measures can be granted by the arbitral tribunal during the arbitral proceedings or at any time after making the arbitral award. And also, according to this provision it ensures that any order that any arbitral tribunal issued by the nature of the interim measure shall have to treat as a order given by a Court for all purpose and it is also enforceable before the law as well as any other order grated by the Courts under the Code of Civil Procedure 1980 of India. This provision is to empower and to facilitate the arbitration procedure in the level of the Court practice and also to minimize the court intervention and establish the arbitration in an independent manner.

Amendment to section 24- this provision introduced a progressive provision which can enhance the effectively of the arbitration. According to that in a arbitration it shall hold an oral hearing for the presentation of evidence or oral arguments on a day-to-day basis and shall not grant any adjournments without a sufficient cause which cause unnecessary misunderstanding about the arbitration.

New provision as section 29 A- this provision traduced more enhancing features to the arbitration with a structure of time limits.

- The arbitration shall ensure speedy completion of arbitration proceedings and pass the award within a period of twelve months from the date when the tribunal enters upon the reference.
- Parties may extend such period for a further period not exceeding six months
- If the award is made within a period of six months, the arbitral tribunal shall be entitled to receive additional fee as the parties agree.
- If the award is not made within specified period or extended period, the mandate of the arbitrator shall terminate unless the time is extended by the court.

The professionals involve in the construction industry have the responsibility to increase the effectiveness of the arbitration. The arbitrator needs to possess a strong personality on displaying humility, empathy and understanding for the burdens that the disputing parties have to bear. In addition to the characteristics which should have to a good arbitrator such as confidentiality, availability, voluntariness, conflict of interest, fairness and interpreting ability. The results of this study can be used to increase the effectiveness of arbitration in construction industry of Sri Lanka.

7. CONCLUSIONS

The rapid globalization of the economy and competition has led to exponential problems in arbitration in built environment. This has led the court system overburdened and it would cause the slow adjudication of commercial kind of disputes. Hence, arbitration process become critical for construction sector which could facilitate a prevalent mode of dispute resolution for commercial disputes. The Construction Industry Development Act (CIDA) do not encourages Arbitration as an effective ADR method. Instead Section 50, 52 under Part IX of the Act encourages Adjudication as the ADR method of settlement of disputes. This situation itself discourages a necessity of binding decision towards dispute resolution in construction industry which already requires to be enhanced. In the construction industry of Sri Lanka, no adequate concern given as to how the fundamentals of engineering and law must be used in the process of managing disputes. The importance of adopting fundamentals of engineering principles as adopted in other aspects of construction processes must be emphasized in every instance of the dispute management process as well. There has to be a contribution to the industry by way of using scientific methods for programming, monitoring, evaluations, analyses which should form the basis of scientific dispute resolution. The professionals should persuade the stakeholders to adhere to the fundamentals of engineering, law and ethics in the process of dispute management in order to have a more sustainable and healthy construction industry. If it is organized under a well-designed structure of laws and regulations specially under Arbitration Sri Lanka will be experienced a progressive Arbitration which will encourage the attraction of the construction opportunities.

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RISKS ASSOCIATED WITH PHYSICAL ASSET MANAGEMENT: A LITERATURE REVIEW

P. Thatshayini, Damitha Rajini* and A.S. Weerasinghe

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Accelerated physical asset operations in organisations are necessitated in order to sustain within the competitive business environment. These asset operations involve a number of risks. The management of risks associated with physical assets as well as their operations is an essential element of Physical Asset Management (PAM). Although there is a growing interest in PAM around world, a lack of consideration of risks associated with PAM is evident. However, it is believed that a proper understanding of these risks is essential for effective Physical Asset Risk Management (PARM). Accordingly, the aim of this paper was to review the existing literature to investigate the risks associated with PAM. A comprehensive literature survey referring data sources, and a subsequent desk study were carried out in order to achieve the above aim. The study identified thirty-five risks, which could be categorised under six (06) groups as 'physical failure risks', 'operational risks', 'risks associated with natural environmental events', 'risks associated with the factors outside the organisations' control', 'stakeholders related risks' and the 'risks associated with different lifecycle phases of assets'. Giving a prior concern for the identified risks and reviewing the exposure level of each risk towards PAM will support the organisations to evaluate the risk levels and make decisions on risks mitigation. This will provide the organisations with a smooth operation of physical assets and numerous benefits associated with it.

Keywords: *Physical Assets; Physical Asset Management (PAM); Physical Asset Risk Management (PARM); Risks Associated with PAM.*

1. INTRODUCTION

The emerging discipline of risk-based approach to manage physical assets has received an increased popularity during the last decade. By acknowledging and paying attention to risks associated with Physical Asset Management (PAM), they can be effectively mitigated (Gichun, 2015). Therefore, understanding the associated risks is important to ensure effective PAM in an organisation. Though there are some studies on risk management of physical assets, the researches which have specifically addressed the risks associated with PAM are hardly found. Thus, the risk factors associated with PAM are unknown (Jeeva & Baswaid, 2014). Therefore, this study aims to review the existing literature and investigate the risks associated with PAM in order to increase the present level of awareness on risks which can be associated with PAM. The paper structure begins with an introduction to the study followed by a description of the method adopted in this research. The findings of the study are discussed in the next section. Finally, the paper presents the discussions and conclusions derived from research findings with the way forward.

2. RESEARCH METHOD

A comprehensive literature review on a broader perspective was conducted to identify the risks associated with PAM referring to published literature on journal articles, conference proceedings, and reports from government and non-government associations, articles from websites, etc. Due to the limitation of empirical studies on literature relating to risks associated with PAM, the literature on physical assets, PAM and Physical Asset Risk

*Corresponding Author: E-mail - damithar@uom.lk

Management (PARM) were comprehensively reviewed. Accordingly, thirty-five (35) risk factors were identified from twelve (12) literature sources. After a desk study, the identified risk factors were classified as per the classification of ISO 55000 standard for asset management, into six (06) main categories (Refer Table 1). Hence, both through the literature review and desk study, the research question of the current study; i.e. what are the risk factors associated with PAM?, was answered.

3. RISKS ASSOCIATED WITH PHYSICAL ASSET MANAGEMENT: AN OVERVIEW

According to the ISO (International Standard Organisation) 55,000, an asset is an item, an entity or something that has the actual or potential value for an organisation (ISO 55000, 2014). There are many types of assets relevant to all process industries such as physical, human, information, financial and intangible assets (Robert, 2017). Physical assets have a useful life greater than a year and are expected to earn income sufficient to cover the operating expenses and amortized acquisition cost associated with it (Theron, 2016). According to Mardiasmo *et al*. (2008), efficient allocation and management of physical assets are crucial in order to maximise the performance and fulfil strategic goals. Therefore, PAM is a fundamental element in an organisation's operations.

PAM has come to the forefront recently, in order to help assets and activities to exploit the full potential of the organisations and effectively reach their business goals (Malestic *et al.,* 2016). It includes a set of disciplines, approaches, techniques, applications, and tools to optimise the value of physical assets (Ratnayake & Markeset, 2012). To gain a greater value, the PAM process should extend from design, procurement, and installation through operation, maintenance and retirement over the complete asset lifecycle (Blanchard & Fabrycky, 1998). Further, PAM is a complex part of any organisation and must be treated as such, in order to strike the right balance between performance, cost and risk in pursuing the organisational goals (Emmanouilidis & Komonen, 2013). Hence, PAM is regarded as an essential technical as well as a business process.

According to Bharadwaj *et al.* (2012), a risk is a combination of the probability of uncertain event and its consequence. Good PAM approach helps to improve asset performance and to handle risks effectively (Dean, 2014). The general purpose of risk management is to understand the cause, effect, and likelihood of negative events and to optimally manipulate associated risks to an acceptable level (Transpower New Zealand Limited, 2013). Accordingly, PARM functions are to understand the causes, effects and the likelihood of adverse events which may occur while an asset is managed (British Standards Institution, 2008). Running a business that does not have an adequate PARM system will lead to take unnecessary damages and risks to the organisation, investment, and even to people's lives, without even knowing the risks (Pearson, 2016). According to Proctor and Varma (2012), in the PAM, risk of failure is not only considering the catastrophic failure of physical assets, but also considers the failure to achieve desired condition levels, failure to preserve asset value and failure to ensure desired levels of service. Multiple risks are involved at every step of asset lifecycle. In order to make sure that each asset performs within defined capability limits, risks have to be identified and proper measures have to be placed even before the risks appear (Mittal, 2014).

4. DIFFERENT TYPES OF RISKS ASSOCIATED WITH PHYSICAL ASSET MANAGEMENT

According to the classification of ISO 55000 standard for asset management - overview, principles, and terminology, risks related to PAM can be categorised into six (06) main categories as 'physical failure risks', 'operational risks', 'risks associated with natural environmental events', 'risks associated with the factors outside the organisations' control', 'stakeholders related risks' and 'risks associated with different lifecycle phases of assets'. Due to the international recognition of ISO classification, it was selected to categorise the risks identified through this study. Hence, the identified risks with the respective authors under six (06) types have been shown in Table 1, and they have been discussed in detail under following sub sections.

4.1. PHYSICAL FAI LURE RISKS

According to Deloitte Enterprise Risk Service (2015), gradual deterioration and mechanical breakdowns are top risks associated with physical assets. As mentioned by Network of Associations of Local Authorities of South East Europe (NALAS, 2014), every asset failure or a possibility of failure is a result of asset's poor condition and brings minor or major consequences to the provision of the required level of service. Further, the system components or the whole system can fail due to incorrect installation, incorrect site assembly, incorrect mounting practices, inadequate environmental protection and deficient foundations and supports. Some of the system failures are along with commissioning and operating errors, and these errors that do not appear during equipment infant-life will eventually cause failures during its operating life (Sondalini, 2016).

Table 1: Different Types of Risks Associated with Physical Assets Management

Risks	**Reference Source**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Physical Failure Risks												
Gradual deterioration/ aging of asset			✓			✓	✓		✓	✓	✓	
Mechanical breakdowns of assets/ equipment and sub-components failures									✓		✓	
Operational Failure Risks												
Improper operation of assets (above/below)		✓						✓	✓			
Lack of operational safety			✓	✓					✓			
Improper/inadequate risk planning						✓		✓				
Unclear roles and responsibility/improper structure							✓					
Unavailability of inadequate models and systems to guide asset management (policy & strategy), etc.					✓		✓					
Ineffective information on assets/asset management	✓				✓		✓	✓			✓	✓
Poor management of asset criticality		✓										
Poor spare parts management		✓					✓				✓	
Reactive asset management and maintenance										✓		
Lack of investment in new technologies							✓				✓	✓
Poor contract management							✓				✓	
Service failures (due to changing demand for asset management)			✓				✓					
Risks Associated with Natural Environmental Events												
Natural phenomena and disasters				✓					✓			
Environmental related incidents/damages	✓		✓						✓			
Risks Associated with the Factors Outside the Organisations' control												
Risk of theft/ burglary				✓					✓		✓	
Terrorism/ Sabotage/ Malicious				✓					✓		✓	
Technical obsolescence	✓		✓									
Economical obsolescence			✓		✓						✓	
Environmental obsolescence			✓									
Stakeholders Related Risks												
Lack of participation/attention of some key stakeholders							✓				✓	✓
Lack of commitment from top management							✓					
Incompetency of senior managers to implement developed asset management											✓	
Engineering/ technical skills challenges							✓					
Lack of experiences of technical employees											✓	✓
Negative attitudes and morals of employees											✓	
Poor service delivery by service contractors											✓	
Lack of legal and regulatory compliance									✓			
Rigid organisational culture							✓					
Risks Associated with Different Lifecycle Phases of Assets												
Design and production/ construction errors/defects									✓			
Acquisition risk		✓										
Construction damage									✓			
Lack of proper maintenance (under/over)						✓		✓			✓	
Disposal risks		✓										

1- Rittenberg, *et al*. (2008)
2- Griffin (2010)
3- Dalesio (2012)
4- Brennan & Mattice (2013)
5- El-Akruti & Dwight (2013)
6- Jeeva & Baswaid (2014)
7- Cillia (2014)
8- Gichun (2015)
9- Deloitte Enterprise Risk Service (2015)
10- Canning (2015)
11- Miya & Grobbelaar (2015)
12- Actenum Corporation (2017)

4.2. OPERATIONAL RISKS

As stated by Dalesio (2012), industries have become increasingly intolerant of industrial incidents due to improper operation of assets. Many organisations suffer from a lack of understanding of the inherent design capabilities of their assets and how best to operate within their ranges to optimize the asset lifecycle. For some assets, either operating below or above the design range adversely affects the asset life (Gichun, 2015). Deloitte Enterprise Risk Service (2015) reported that as per the recent incidents, the lack of operational safety is a crucial risk and due to this, the industries have pushed operational safety as a significant risk. According to Institute of Certified Public Accounts of Kenya (2015), inadequate asset planning results in failure to prioritize and determine the feasibility of the organisation's assets towards the achievement of organisation's objectives. As Cillia (2014) pointed out, there is no adequate models or guidelines to direct the PAM. Aligning PAM objectives with organisational strategic objectives is also hardly found and linking them with maintenance, risk management, health and safety and other relevant practices is rarely done (Rajini & Thatshayini, 2017). As a result, most of the organisations follow a set of policies or general and static processes which may not be consistent with the specific needs of the organisation (El-Akruti & Dwight, 2013). Uncertainty regarding the structure which indicates who should be responsible and accountable for making assets decisions, result in delays in taking decisions and this is a huge risk in cases like catastrophic failures.

As mentioned by Miya and Grobbellaar (2015), ineffective or lack of information and support systems to base decisions on is a shortcoming of current PAM processes. Further, it is very difficult to measure the past performance of assets due to ineffective information (Cillia, 2014). Incorrect recording of assets is hidden by complex ownership structures designed to keep assets off the books (Rittenberg *et al.,* 2008). Hence, wrong decisions on asset replacements and improvements are taken due to incorrect estimation of assets' useful life in financial calculations (Komonen, 2009). In addition, the lack of simple practical tools for risk assessments without which it is unsure that what kind of data should be collected to support risk assessments is evident (Miya & Grobbelaar, 2015). As Griffin (2010) stated, there is a narrow concentration given to asset criticality analysis to determine the most significant assets and associated approaches for the development of maintenance tasks. Also, spares criticality analysis is not much practised to determine the inventory category and associated approach for a specific spare or material of emerging concern.

As per Canning (2015), reactive PAM is likely to result in unreliable plant and increased human and financial risks. Reactive maintenance is the process of reacting to failed, ineffective or damaged equipment and repairing or replacing in order for the intended function to be achieved. The main disadvantage of reactive maintenance is the unpredictability of when issues may occur. This lack of knowledge may well result in either labour or materials being unavailable immediately, and therefore delay the time taken for a repair, so that increase the equipment downtime (Gordonw, 2013), being a risk for PAM. Apart from that, most of the organisations are rigid for absorption of innovation due to counterproductive cultural issues. Workers may familiarise to old technologies. Therefore, they resist moving into new innovative technologies. Further, most of the organisation are not willing to spend much on technological investments (Cillia, 2014) which is a risk for effective PAM.

Further, the budgets, resources allocated and information about asset condition and performance are usually obtained in the same format. These activities are done by various departments in the organisation but may not be integrated and optimised for the strategic objectives of the organisation (El-Akruti & Dwight, 2013). As per Emmanouilidis and Komonen (2013), the status of implementation of PAM best practices in the industry is not sufficiently recorded or documented (Emmanouilidis & Komonen, 2013). The poor relationship is the main issue with the organisation and the external contracting people. Due to the poor relationship, expected service level cannot be obtained. Poor contract management with external service providers can negatively impact a business in a variety of ways. Running with sub-standard service levels and chronically poor services, can impact the business potential for profit maximisation as well (McQuerrey, 2012). Accordingly, asset condition reflects the physical state of the asset, which may or may not affect its performance. The performance of the asset is the ability to provide the required level of service to customers. Not knowing the current service level condition and performance of an asset may lead to premature failures. The unforeseen service failure of an asset can have major consequences that constitute a business risk or potential loss to the organisation (Institute of Public Work Engineering Australia, 2009).

4.3. RISKS ASSOCIATED WITH NATURAL ENVIRONMENTAL EVENTS

Natural environmental events can cause failures of physical assets and it only takes a minute for natural disasters such as flood, hurricane and others to happen that will damage the physical assets and stop the business process (Brennan & Mattice, 2013). Moreover, physical assets such as buildings, structures, and engineering systems operate in a dynamic environment where they are exposed to short, medium and long-term variability in ambient environmental conditions (Rayner, 2010) and these weather and climate changes pose a particular risk for assets and operators in all sectors. These risks have the potential to seriously affect the availability and reliability of assets. However, no one pays attention to PARM unless the natural disaster happens to them and affects their business or shuts the operations down (Smith, 2011). Not surprisingly, the saddest part is that most of the industries seemed doomed to repeat their mistakes because they think that natural disasters are a one-time event and remain unprepared.

4.4. RISKS ASSOCIATED WITH THE FACTORS OUTSIDE THE ORGANISATIONS' CONTROL

According to Guard (2017), one of the unfortunate aspects of PAM is confronting the fact that theft happens. Gould (2004) stated that the public, private, and governmental organisations face an increased need to understand and manage the risks to their organisational physical assets with the increased threat of terrorism.

Apart from them, different obsolescence can be experienced when managing physical assets, which cat as barriers for PAM. Theron (2016) described obsolescence as a major risk and require writing off of the value of the obsolete item against earnings to comply with the accounting principle of showing inventory at lower of cost or market value. Further, obsolescence is the significant decline in the competitiveness, usefulness, or value of physical assets. Obsolescence occurs generally due to the availability of alternatives that perform better or are cheaper or both, or due to changes in user preferences, requirements, or styles (Hout, 2016).Technical obsolescence is the state of a fixed asset, service or process when it becomes unwanted or should no longer be used (Wendling, 2012) and when technical requirements are not satisfied (Proctor & Varma, 2012). Economical obsolescence means where the cost to maintain and operate an asset is likely to exceed the economic return expected (Proctor & Varma, 2012). Moreover, economic obsolescence of asset is a form of depreciation where the loss in value or usefulness of an asset (Sytsma & Baumann, 2014). Further, there are unexpected costs associated with physical asset operation. Such as the opportunity costs, unexpected maintenance costs associated with older assets, opportunity cost of lost tax shelter due to expired depreciation, expected loss costs associated with declining reliability of an old asset, costs of time, energy and materials needed above and beyond owning the newest and latest like an asset. When the economic costs reduce the return on investment, the asset is said to be economically obsolete (Wendling, 2012). Environmental obsolescence is the loss of value from causes outside the property itself. This can also be called as external obsolescence. Environmental obsolescence can be identified as environmental hazards, noise, excessive dust, and radon or methane gas issues (Hulsey, 2008). It occures when negative impacts are given by the assets to the environment. Normally, assets operations needs to be environmental friendly. If the asset operations does not comply with the required envirionmental friendy conditions and exceeds the standard exposure levels, then the asset is environmentally obsolete (Proctor & Varma, 2012). Insurance companies take obsolescence into account to reduce the amount of claim to be paid on damaged or destroyed assets.

4.5. STAKEHOLDERS RELATED RISKS

According to Cillia (2014), stakeholders related risks include the disconnections at different levels of the organisation, lack of participation from some key stakeholders and unclear commitment from top management due to little corporate guidelines on reporting and management of physical assets. Moreover, it is difficult to handle physical assets without involving a specified person who has experience and competence in managing assets as there are lot of stages and activities related to PAM. As per the Hastings (2010) and Cesca and Novaes, (2012), mostly, PAM responsibilities and activities are not confined to a specific department. Hence, in some organisations, the decisions related to PAM are taken by the professionals such as general managers who have no sufficient knowledge about PAM, and this will negatively affect the performance of those organisations (Rajini & Thatshayini, 2017). However, as stated by Miya and Grobbelaar (2015), senior managers' incompetence to implement developed PAM strategies is a risk for effective PAM. Therefore, the management should ensure that those who were given responsibilities for PAM are competent and have adequate skills especially, the required engineering and technical skills (Cillia, 2014) and training to perform their duties and deliver the required outcomes, in line with the asset management policy, strategy and objectives. Organisations in developing countries do not consider PAM as an important discipline and do not provide the asset management professionals with adequate training on it (Rajini & Thatshayini, 2017). As per Miya and Grobbelaar (2015), in most of fields, employees who operate and maintain the plants are not keen to know the details about PAM. This is because employees feel that the top management does not involve them and take their opinions about daily operations and maintenance, and this negative morale is a risk for effective PAM.

Most of the organisations do not have a clear idea of the separation of the role of asset manager from the service provider. This has caused friction between the departments, de-motivation of employees and increased complexity and requirement for double work and inefficiencies. Also, the extra amount of time and manpower has negatively influenced the financial efficiency and the organisational effectiveness (Gaarenstroom, 2014). According to Justin (2018), asset owners face risk factors from financial and health, to safety and environmental due to poor service delivery by service contractors. To mitigate these risks, service providers, need to know exactly their responsibility, condition of assets and how assets should be maintained in order to maintain the asset value. Further, physical assets are aging due to lack of information and external service providers take advantage of this situation by delivering poor services as well (Miya & Grobbelaar, 2015).

According to the survey results of Deloitte Enterprise Risk Service (2015), 43% of companies have accepted regulatory compliance as a crucial risk. Hence, it reveals that the legal and regulatory compliance as a main criterion in evaluating asset risks in the industry. Most of the organisation struggle with establishing an effective PAM within their organisations. The simple reason behind this is that PAM needs a change management to work. Rigid organisational culture always resists to improve and adapt with standardised PAM system (Joubert, 2017). Some recent studies indicate that PAM is not always given the priority and attention that is merited. Countless operational experts will retire over the next decade and the retiring maintenance or engineering experts may have known about the advanced PAM knowledge. Since asset owned organisations tend to outsource more than before, there is a danger to lose 'Asset Knowledge' (Komonen, 2009).

4.6. RISKS ASSOCIATED WITH DIFFERENT LIFECYCLE PHASES OF ASSETS

As Griffin (2010) pointed out, there is a lack of consideration on asset acquisition to determine issues that should be included in the specification of the assets, such as training, integration of systems, energy considerations, critical spares, etc. Any mistake in the working processes within design and construction stages ultimately leads to errors that affect the durability, performance, reliability, maintainability, availability, and safety of the systems (Ab Ghani *et al.,* 2017). Moreover, Keqa (2016) mentioned that the acquisition planning includes activities involved in purchasing an asset with the aim of ensuring cost-effective acquisition. This covers activities such as designing and procuring of an asset. Appropriate application of these activities will guarantee that the asset is fit for use. If there is any risk associated with acquisition process, there will be an issue to meet service delivery and other organisational objectives.

The risk to the firm's business processes and key facilities due to the unavailability or improper maintenance of physical assets have been reported by a number of researchers (Miya & Grobbelaar, 2015; Hoffman, 2002). Maintenance is often viewed as a business expense open to cutting like any other in order to maximize profits. With these pressures, maintenance departments are constantly struggling with how to balance the cost with the performance requirements such as reliability and uptime (Gichun, 2015). The key issue regarding over maintenance typically involves two issues that will make the PAM system ineffective. Firstly, there is generally a significant cost associated with the execution of non-value-added maintenance. Secondly, the typical organisation that can be accused of over-maintaining its assets will most likely be performing intrusive maintenance tasks more frequently. The issue of under-maintenance and how it prevents effective PAM is even more clear-cut (Gichun, 2015).

Apart from them, the disposal of assets is an area where the risk of corruption is high (Crime and Corruption Commission, 2017). In most of the organisations, there is the unavailability of disposal risk assessment to identify assets that should be disposed of and any issues that should be considered during the disposal process (Griffin, 2010). If the disposal process is not supported by competent and professional advice and the use of accurate and relevant information, this may result in an inadequate return on the disposal of buildings and poor coordination of cash flow with capital investment requirements (Queensland Department of Housing and Public Works, 2017). Further, failure to replace old assets have led to high energy consumption, high maintenance costs and increased risk of accidents and calamities. On the other hand, organisations have experienced negative impacts due to unnecessary replacement of physical assets (Madusanka *et al.,* 2016).

5. DISCUSSION

Following the above discussion, it was identified that PAM could fail in many ways. There are definitely six types of risks which critically contribute to an organisation's failure to manage physical assets efficiently. Most of the risk categories are interconnected. As per the above highlights, operational risks factors contribute to risks associated with physical failure and different life cycle phases of assets. On the other hand, operational risks could be occurred due to factors outside the organisation's control such as economic obsolescence. Furthermore, the risks associated with natural environmental events and factors outside the organisation's control such as environmental obsolescence are interconnected. In addition, the stakeholders' related risks and operational risks are interconnected by means of risks associated with commitment of managerial level, delegation of authority, training and experience and legal and regulatory compliance towards physical assets.

As seen from Table 1, almost all the sources indicated that operational failure risk factors as risks associated with PAM, whereas, 50% of the sources indicated physical failure risks and risks associated with the factors outside the organisations' control. Other risks; risks associated with different lifecycle phases of assets, natural environmental events and stakeholders' related risks were identified by 25% of the sources as the risks associated with PAM. Accordingly, operational failure risks have been highest discussed by different authors as PAM related risks. Considering the risk factors identified under the operational risks category, ineffective information on PAM has the priority, whereas, aging of assets is the highly addressed under physical failure risks. The risk of theft, burglary, terrorism, sabotage and malicious have received more concentration as the risk factors outside the organisations' control. On the other hand, lack of proper maintenance has been identified as the major risk under risks associated with the different lifecycle phases of assets. Environmental related incidents/damages and lack of commitment of key stakeholders are also highlighted by the authors as significant under the risks of natural environmental events stakeholders' related risks respectively.

Further, most of the above categorised risk factors will directly impact on the continuation of core operations. Amongst, the highly influential factors are found under the operational risks category. For example, inadequate asset planning could be caused to poor achievement of organisation's objectives due to prioritize and determine the feasibility of the organisation's assets, whereas, the unexpected service failure of an asset constitutes a business risk or potential loss to the organisation. Considering the physical failure risks, the replacement of physical assets due to aging or deteriorating are extremely expensive and the organisations face financial difficulties. Therefore, physical assets oriented organisations need to have clear concentration on risks associated with PAM to take the necessary steps to identify and mitigate the adverse impacts.

6. CONCLUSIONS AND WAY FORWARD

The study focused to investigate the risk associated with PAM and it was limited to carry out a literature review and a desk study to drive the findings. Overall, thirty-five (35) risks were identified through previous studies and categorised as 'physical failure risks', 'operational risks', 'risks associated with natural environmental events', 'risks associated with the factors outside the organisations' control', 'stakeholders related risks' and 'risks associated with different lifecycle phases of assets'. Prior identification of risks related to PAM helps to understand the cause, effect, and likelihood of adverse events occurring in future. By realising the risks exposure level, the organisations can optimally manage such risks to an acceptable level and it will strongly impact to have a proactive PAM. The identification of risk of PAM should be done when planning, obtaining and receiving the physical assets and during operational, maintenance and disposal stages of the physical assets

The findings revealed that more attention has been given to address the operational risks. Ineffective information on PAM has the prior concern under operational risks. On the other hand, aging of assets is the highly addressed under physical failure risks categorisation while, natural disasters and environmental conditions are not that much addressed by researchers. However, few authors have highlighted that natural environmental events also can be the risks to manage physical assets. Furthermore, the risk of theft, burglary, terrorism, sabotage and malicious have received more concentration as the high risks under the risks associated with the factors outside the organisations' control. Lack of participation from some key stakeholders has been highly addressed under stakeholders' related risks. Finally, lack of proper maintenance is the major risk which has been highly addressed by authors under 'risks associated with the different lifecycle phases of assets.

Accordingly, it is clear that though there are number of risks which restricts effective PAM, a very limited attention has been received for in depth studies on management of those risks. Hence, the article motivates an agenda for future research that advocates a critical review of risks related PAM which could be identified through this study, and evaluation of the critical exposure levels of those risks in Sri Lankan organisations.

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SDGS: ISLAMIC PROJECT FINANCE FOR INFRASTRUCTURE PPPS IN SUB-SAHARAN AFRICA

Abdullahi A. Umar[1*], Mahadi Ahmad[2], Abdul Rashid Abdul Aziz[3] and Zeenat Yusuf[4]

[1]Military Technological College, Muscat, Sultanate of Oman

[2]International Shari'ah Research Academy for Islamic Finance, Kuala Lumpur, Malaysia

[3]School of Housing Building and Planning, Universiti Sains Malaysia, Penang, Malaysia

[4]International Institute of Islamic Banking & Finance, Bayero University, Kano, Nigeria

ABSTRACT

Sub-Saharan Africa (SSA) is the region with the highest number of countries that did not meet the Millennium Development Goals (MDGs) which expired in 2015. Meeting the newly established Sustainable Development Goals (SDGs) is inextricably linked to the availability of quality infrastructure. The current slowdown of the post-global financial crisis economy is already threatening to hinder the ability of SSA to meet the new SDGs. Without investments in key infrastructures that support a modern economy such as roads, electricity and safe water and sanitation, SSA may not meet the new SDGs targets. The past PPP-based conventional debt-financed solutions to SSA infrastructure have failed to produce the desired results and are being terminated. A growing body of empirical studies points to the conventional debt-finance used as a major weakness of the PPP model. The pressure to meet lender's debt repayment covenants force Project companies to pushback scheduled maintenance, and critical infrastructure investments leading to contract breaches and eventual cancellations. This article seeks to highlight why SSA countries should adopt Islamic project finance for PPP financing. We argue that Islamic project finance will eliminate the pressure of meeting specific debt service covenants, lower the cost of services, ensure service sustainability, affordability, and will assist SSA countries meet the new SDG targets. Islamic project finance instruments are partnership-oriented, equity-based, share risks and are compatible with SDGs.

Keywords: *Conventional Debt Finance; Islamic Project Finance; PPP; SDGs; Sub-Saharan Africa.*

1. INTRODUCTION

The millennium development goals (MDGs) which expired in 2015 were developed and agreed to by 189 countries with the purpose of ending extreme poverty globally. And modern infrastructure provision was seen as one of the most important tools for achieving the various MDG targets. However, sub-Saharan Africa (SSA) was the region with the highest number of countries that did not achieve their MDG targets (JMP, 2015). Only 5 countries out of the 53 assessed score up to 50% in the MDGs Global Track Index (Spooner, 2014). A new and more comprehensive set of goals called the Sustainable Development Goals (SDGs) have now been agreed for another 15 years ending in 2030. Without the relevant infrastructures that underpin modern economic development, achieving the new SDGs will still remain elusive for countries in SSA. Infrastructure is both an *explicit* and *implicit* component of the SDGs' goals and targets (World Bank, 2017a). The infrastructure dependent SDGs include *goal 3* (health), *goal 4* (Education), *goal 6* (water supply & sanitation), *goal 7* (Energy), and *goal 9* (all other infrastructures). SSA lags behind all other regions of the world in all infrastructure class except *unpaved roads* (Loxley, 2013). The World Bank estimates that SSA's infrastructure deficit holds back its economic growth by 2% each year (WEF, 2013). In order to catch up with the rest of the world, it has been reported that SSA would require $93billion investments annually comprising $60billion for capital expenditure and $33 billion for Operation and maintenance (Foster & Briceno-Garmendia, 2010). Providing

*Corresponding Author: E-mail - abdulproject@yahoo.com

the required infrastructure would require substantial investments beyond what national governments in SSA can afford through tax revenues. Although SSA governments, foreign aid and private sector are making combined investments of about $45 billion, there still exists a funding gap of $48billion. Governments in SSA have attempted to close the infrastructure funding gap using Public Private Partnerships (PPP) model. However, the poor performances being recorded globally and in SSA across numerous projects have led to anti-PPP sentiments, terminations, cancellations and remunicipalisations. The World Bank in its "*2016 annual PPP update*" acknowledges a 37% reduction in financing and a 27% reduction in number of PPP projects globally (World Bank, 2017b). Furthermore, as many as 235 PPP water contracts have been cancelled globally due to performance-related issues from 2000 to 2015 (Kishimoto et al., 2015). In Germany, 72 PPP electricity contracts were also cancelled for poor performance and remunicipalised (Wagner & Berlo, 2015). PPPs are financed using a highly leveraged project finance structure in the realms of 90%-10% debt-to-equity ratio (NAO, 2018; World Bank, 2017c; World Bank, 2014). There is a growing body of empirical evidence suggesting that the excessively high leveraged structure used in financing PPPs increases risk of default (Nthatisi, 2016; Hall, 2015; Ehrhardt & Irwin, 2004). To avoid defaulting, project sponsors make debt repayment rather than service delivery the focus once operation starts (Ehrhardt & Irwin, 2004). This results in the private consortium's inability to meet contractual obligations. Breach of contracts related to lack of infrastructure maintenance and agreed infrastructure investments is a major reason for contract renegotiations, cancellations and remunicipalisations (Hall, 2015; Kishimoto et al., 2015). The uncontrolled use of conventional project finance structure for PPPs is creating a debt load that impacts the *sustainability* of the provided infrastructure (Nthatisi, 2016). And the need to design tariffs to ensure full cost recovery consequently creates affordability problems leading to service disconnections and inability of the provider to realise the required revenue.

Therefore, the challenge for SSA is to identify alternative sources of *equity-based* financing for its infrastructure to overcome the *full cost recovery* trap of debt finance, share risks and reduce the distortions to efficiency caused by debt guarantees and interests payments. The need for full cost recovery affects tariff design and consequently service affordability. Affordability is a problem for low-income consumers in most countries, in particular in the water sector and in the Commonwealth of Independent States (CIS) (Fankhauser & Tepic, 2007). Therefore, an appropriate financing for SSA countries should improve service affordability and increase value for money (VfM) of projects. VfM provides the same quality and quantity of services at a lower overall cost (Cruz & Sarmento, 2017). Multi-lateral development banks pushing PPPs in SSA are already exploring the application of Islamic finance to enhance sustainability and affordability (World Bank, 2017a; World Bank and IsDBG, 2016). Therefore, this article seeks to draw the attention of SSA policy and decision-makers to the potentials of Islamic project finance in solving their infrastructure financing challenges while enhancing service affordability and laying the foundation for achieving the SDG goals. We argue that adopting Islamic project finance by SSA governments will eliminate the pressure to meet lenders' stipulated debt service obligation, ensure sustainability and enhance service affordability. The rest of the article is structured as follows; *section 2* describes the impact of infrastructure shortfall in SSA, *section 3* explores Current experience with conventional debt-financed PPPs globally, section 4, provides insights into Islamic finance and its financing instruments while section 5 concludes.

2. IMPACT OF INFRASTRUCTURE SHORTFALL IN SSA

In the *water supply subsector*, there is a general lack of access to clean, and safe domestic water supply, making SSA the region with the highest Diarrhoea deaths of children below the age of 5 years. In 2015, SSA had the highest percentage of under-five deaths at 81 per 1000 live births (WHO, 2016). SSA still remains the region with the highest number of people without access to safe drinking water (WaterAid, 2011), and the impact is that there are more people without access to water in 2015 than in 1990 (Scanlon et al., 2016). This poor progress in the water supply subsector has meant that only 43% of the population has access to safe water supply sources and only 32% have access to improved sanitation (JMP, 2015).The poor coverage of water and sanitation leads to an estimated annual productivity loss of about $28.4 billion (UN-Water, 2009). Consequently, improving sanitation and water supply in SSA would lead to annual benefits worth $10 billion and $3.2 billion respectively (Hutton, 2012). However, between 1990 and 2011, only a meagre $300million was invested in the water subsector in SSA (Loxley, 2013).

In the *transport subsector*, Sub-Saharan Africa did not receive any form of private investments neither did it commission any projects in the water supply and sanitation subsector in 2014 as shown in Table 1 below. The simple reason for the lack of private investments is that the private sector allege that the projects are not 'bankable', another word for profitable.

Table 1: Investment Volume and Number of Projects by Region

		Percentabe of total investment earned by regions (2014)						
Sector	Total value of Investments (2014)	**LAC**	**EAP**	**MNA**	**ECA**	**SAR**	**AFR**	**Total**
Transport	**55.3Billion**	82%	3%	<1%	9%	6%	0%	100%
Water supply & sanitation	**4.1Billion**	90%	7%	3%	0%	0%	0%	100%
Energy	**48.2Billion**	41%	20%	6%	20%	7%	5%	99%
Sectors		**Number of projects**						**Total**
Transport		26	3	1	4	15	0	49
Water supply & sanitation		12	20	1	0	0	0	33
Energy		72	23	11	19	25	7	157

Source: Adapted from PPI database

The poor conditions of roads in SSA reduces the useful lifespan of vehicles, the life of tires, fuel efficiency, and increases maintenance costs of vehicles (Teravaninthorn & Raballand, 2008). This results in higher cost of goods and services as manufacturers transfer these costs to consumers. Many opportunities, such as the production of high-valued fruit crops and nuts, are unexploited due to the inability of farmers to bring these goods to market in urban centres (Naudé & Matthee, 2007). Furthermore, Inland transport costs and time delays are a much larger share of total export costs and time for landlocked countries in SSA (Christ & Ferrantino, 2009).

In the *energy subsector,* the World Bank reports that the combined generation capacity of the 48 countries in SSA is roughly the same as that of Spain (World Bank, 2013). Electricity is a key factor in the fight against poverty and elimination of inequalities in SSA (Hall & Niekerk, 2013). The entire SSA is only able to provide electricity for about 31.7% of its population and the number without access is rising (IEA, 2014). The IEA report went further to assert that the "severe shortage of essential electricity infrastructure is undermining efforts to achieve more rapid social and economic development, necessitating widespread and costly private use of back-up generators running on diesel or gasoline". These alternative sources of electricity and energy are a leading cause of illness and deaths among low-income neighbourhoods in South Africa (Eberhard & Von Horen, 1995). The use of generators, wood, paraffin and biomass have adverse health and environmental impacts including respiratory diseases, with whole families dying due to inhalation of toxic generator fumes. SSA has consistently been unable to reach its growth potentials due to absence of key infrastructure that support growth.

3. PERFORMANCE OF PPP PROJECTS

In the early 1990s, the world woke up to privatization as espoused by Multilateral Development Banks (MDBs) and donor agencies. Bouyed by the PPP debate in terms of 'public is bad, private is good' allegedly on the basis of selective evidence (Loxley, 2013); SSA governments accepted the new infrastructure 'silver bullet'. SSA governments eager to please lenders and donors alike quickly sold off national assets and privatized public services as a pre-condition for loans (Pigeon, 2012). Almost 3 decades after, most of the concessions and privatizations have been reversed, cancelled, renegotiated or abandoned (Gualberti et al., 2009). It is increasingly being found that there is no difference between public & private ownership in terms of efficiency & environmental violations (Perard, 2009); and in terms of costs (Kirkpatrick et al., 2006). A review of all published econometric studies of water and waste privatisation since 1970, found little support for cost reduction as a result of privatization (Bel & Warner, 2008). Another comparative study of 301 Privatised and 926 public utilities in both electricity and water across 71 developing countries found that the involvement of the private sector did not lead to any significant investment gains (Gassner et al., 2008). Across developing countries, concessions failed to invest what they had originally committed to investing, and did not always meet their original contractual targets for coverage (Philippe, 2009). In Argentina, a 95 years concession signed in 1998 was cancelled due to under investments (Izaguirre & Perard, 2010). In SSA, 17 lease & management contracts in the water sector did not result in any investments by the private consortium (Hall & Lobina, 2006). It was also reported that from 1990-2009, no new water projects were signed in SSA while about 51 existing concessions were cancelled within the same time (Izaguirre & Perard, 2010). The authors also report that PPP projects in the water sector fell by as much as 46% in 2009. Consequently, SSA is reputed as having the highest number of cancelled water contracts (Philippe, 2009). As a result of the many failures experienced, infrastructure finance to developing countries from international sources has declined by almost 50% (Auriol & Blanc, 2007).

After cancellations of concessions, the water utilities in these countries have improved access and quality of water with corresponding increase in maintenance and renewal of water infrastructure (Kishimoto et al., 2015). For instance, in the first year of cancellation in Paris, the new public-operated water utility realised savings of 35 million Euros which allowed for an 8% drop in water tariffs. Transport for London (TfL) also realised a savings of about 476 million pounds after terminating 3 ppp deals (NAO, 2018). Consequently, private involvement in infrastructure is declining globally (Hall, 2015; Kishimoto et al., 2015). It has been reported that PPPs declined by 24.1% in low-middle income countries (Gutman et al., 2015).

In developing countries, despite efforts to elevate the energy issue by the United Nations, actual investment decisions by MDBs has failed to align with approaches that will ensure the goal of energy for all is achieved (Sierra Club, 2014). This non alignment of MDBs and donor agencies' policies with the needs of developing countries in SSA is responsible for the continued failure of MDBs-linked development projects. One study of the World Bank & its private sector arm, the IFC, found that both organisations have a failure rate of over 50% on all its African projects (Ika et al., 2012). A major factor in all the failures reported is the pressure to design tariffs which guarantee full cost recovery, capable of covering interests and debt repayments including profits for shareholders and investors. SSA needs cheaper sources of infrastructure financing if they are to meet the SDGs. A source of financing that will make it possible to design tariffs that are affordable to low income earners. One thing policy makers tend to ignore is that, there can be no sustainable development unless affordability dominates the thinking of the authorities (Pape, 2002). It is interesting to note that despite the critical nature of water and energy shortages in SSA, existing PPPs in these sectors are experiencing growing number of cancellations and terminations without being replaced by a more credible system. Table 2 below shows some of the water and energy concessions that have been cancelled in SSA countries. Affordability issues, inability of concessionaires to fulfil infrastructure investment covenants and inability of revenue to cover debt service obligations are the major reasons for these cancellations and terminations (Hall, 2015; Kishimoto et al., 2015; Pape, 2002).

Table 2: Status of Some Water and Energy Concessions in SSA

	Water Concessions Status in SSA		
S/No	**Countries**	**operator**	**Status/Reason**
1	Tanzania	Biwater-UK	Contract Terminated
2	Mozambique (Maputo)	Aguas de Portugal- Portugal	Contract Terminated
3	Central African Republic	SAUR	Contract Terminated
4	Guinea	SAUR & VEOLIA	Private operator withdrew
5	Mali	SAUR	Contract Terminated
6	South Africa (fort beaufort)	SUEZ	Contract Terminated
7	South Africa (stutterheim)	SUEZ	Contract Terminated
	Energy concessions status		
	Countries	**operator**	**Status/Reason**
1	Chad	STEE	Cancelled
2	Gambia	MSG	Cancelled
3	Senegal	SENELEC	Cancelled
4	Rwanda	Kibuye Power	Cancelled
5	Mozambique	Energia de Mocambique	Cancelled
6	Gabon	Gabon (SEEG)	Distress

Source: Compiled from Lobina *et al.,* 2014 and Gualberti *et al.,* 2009

The use of debt-based financing often increases the cost of infrastructure astronomically. This is because during the construction period, the project debt grows while there are no revenues from the project to service interest payments which are then added to the debt and compounded (Flyvbjerg, 2016). However, studies show that project sponsors prefer *debt-finance* over *equity-based financing* for a number of reasons. Firstly, interests on debt is tax deductible, while equity is taxed. Secondly, debt is also cheaper than equity and debt helps sponsors spread risks among other benefits (World Bank, 2017c; World Bank, 2014; Yescombe, 2014, p.24). Finally, higher leverage increases returns for investors (Yescombe, 2014, p.21). However, the cost of capital resulting from debt finance is a critical factor in achieving Value for Money (VfM) on PPP projects (Cruz & Sarmento, 2017). SSA countries are seen as high risk in the international development finance community. And the cost of capital increases with a country's risk profile, leading to higher interest rates for projects loans in SSA countries.

4. ISLAMIC PROJECT FINANCE: RAISING CAPITAL

The global Islamic finance industry is reported to own almost $1.8 trillion dollars in assets at the end of 2013 (IMF, 2015), which was expected to reach $2.6 trillion dollars by 2017 (PricewaterhouseCoopers, 2013). Given the principles of Islamic finance that support socially inclusive and development promoting activities, the Islamic financial sector has the potential to contribute to the achievement of the Sustainable Development Goals (Ahmed et al., 2015). Financing can be raised by Islamic financial institutions in one of two ways: through depositor's investment accounts or through the issue of Sukuks (the Islamic equivalent of bonds). Sukuk offers an investment solution that complies with the requirements of the Islamic faith, and a debt instrument that has, since the global financial crisis, been perceived as less risky than conventional bonds given its asset-backed nature (Billington & Taha, 2018). Sukuks are not true interest-bearing instruments, but are structured in a way to channel rents, changes in capital gains/losses, or income to investors in periodic payments (OECD, 2015). Sukuks have become the most common methods of raising capital under the Islamic finance industry. Sukuks are either asset-based, meaning the investor is a part owner of the asset to the tune of their investments or asset-backed, giving the investor rights to a stream of income from the underlying asset. Motivated by a heightened interest in financial instruments that emphasize risk sharing, it has been attracting greater attention in the wake of the recent financial crisis (Mohieldin, 2012). Consequently, Islamic financial products have been deployed by non-Muslim majority countries such as Germany, Luxembourg, Singapore, Hong Kong, France, Japan, China and the UK (IIFM, 2016). Many people attribute this interest from non-muslim majority countries to the weaker performance of conventional instruments during the global financial crisis. With increasing recognition of the risk sharing value of equity over debts, many countries and projects in the European countries are making a purposeful shift towards increased equity in privately financed infrastructure (NAO, 2018). Sukuks help pool resources from a broad investor base while emphasising risk-sharing and equity-based financing arrangements which restrains excessive leveraging.

Furthermore, in financing infrastructures, IFIs are more like business partners and have a stronger incentive to monitor and ensure the success of a project as their profitability and repayment is tied to the performance of the asset. Under conventional project finance, financiers often seek government guarantees of full debt repayment before committing funds especially on African projects. This creates distortions to efficiency and does not provide incentives for the project sponsor to ensure success. Project sponsors are often capable of abandoning projects due to their low equity investments and the fact that they could use some form of creative accounting to limit their losses. The London underground PPP failed as a result of a combination of these conditions under conventional finance. Department for Transport (DoT) guaranteed 95% of the private debt for the London underground PPP which had 88.3% debt-finance at an interest rate of 20%; yet it had no direct oversight of the operations of the PPP (Williams, 2010). Under Islamic project finance, the involvement of the lender as a partner can help project sponsors work through bad times thereby lowering the pressure to sell assets at 'fire-sale' prices, and in the process protecting against fall in asset prices and probability of cascading default (Mohieldin, 2012).

4.1. ISLAMIC PROJECT FINANCE INSTRUMENTS

Like its conventional finance counterpart, Islamic project finance has different financing instruments which could be deployed independently or in combination with other instruments to deliver infrastructure projects. While *Sukuks* are the vehicle for raising capital from investors, Islamic financial instruments dictate the manner in which profits and losses are shared in the venture. The most commonly used Islamic finance instruments include *istisna* (mainly for construction), *Ijarah* (Lease financing), *Murabaha* (Cost-plus contracts), *Mudarabah* (a form of trust financing contract) and *Musharakah* (a partnership contract).

Partnership is one of the best contributions of Islamic finance which distinguishes it from conventional finance (Abushareah & Naim, 2015). The *Musharakah* (a partnership contract) financing instrument will be the focus of this section owing to its partnerships based nature. The musharakah financing method involves the SPV and the government contributing to a common fund for the purpose of investment in infrastructure akin to today's PPP partnership arrangements. The profits from the venture is shared between the partners according to a pre-agreed ratio as shown in Figure 1 below, but losses are shared according to each partner's contributions (Obaidullah, 2005). It is permissible to partner with non-muslims or conventional banks as long as the venture is permissible under shari'ah and subject to Shari'ah supervision (AAOIFI, 2015). *Musharakah* has a variant called *'diminishing musharakah'* under which a provision is included in the contract permitting one of the partners (usually the government) to gradually buy-off the other partner. This is the instrument that closely mirrors the Build-Operate-Transfer (B.O.T) commonly used for PPP projects globally. This instrument will be a more suitable vehicle for SSA countries considering their lack of domestic investment funds. Furthermore, for strategic and security reasons, it is not wise for foreign SPVs and banking institutions to own a country's critical infrastructure such as ports, airports, water supply system etc. Therefore, an arrangement such as this where the host government can gradually buy-out its partner overtime is best suited to SSA. The point here is that social conflicts affect the performance of international projects (Al-Sibaie et al., 2014). These conflicts are often the result of various domestic interest groups who view completely foreign ownership or control of public infrastructure in bad light thereby constituting non-commercial risks to the project. Therefore, these non-commercial risks can be reduced by increasing the share of local interest groups or government in the project in absolute terms (Bendjilali & Khan, 1995). The diminishing *musharakah* helps to achieve this outcome more easily while ensuring sustainable service provision, affordability and technology transfer between the partners. Using Islamic finance for PPPs eliminates the need to generate specific stipulated monthly or yearly revenue. Whatever revenue is generated is shared among the investors after deducting operational costs. Citigroup's Chief Economist, Willem Buiter, said 'although the motivation for diminishing *musharakah* may be to adhere to religious codes, but it is a less risky financial arrangement that could solve household debt burdens in the western world' (Shapiro, 2016). Currently, *Musharakah* constitute about 16% of corporate sukuk issues from 2001-2015 (IIFM, 2016).

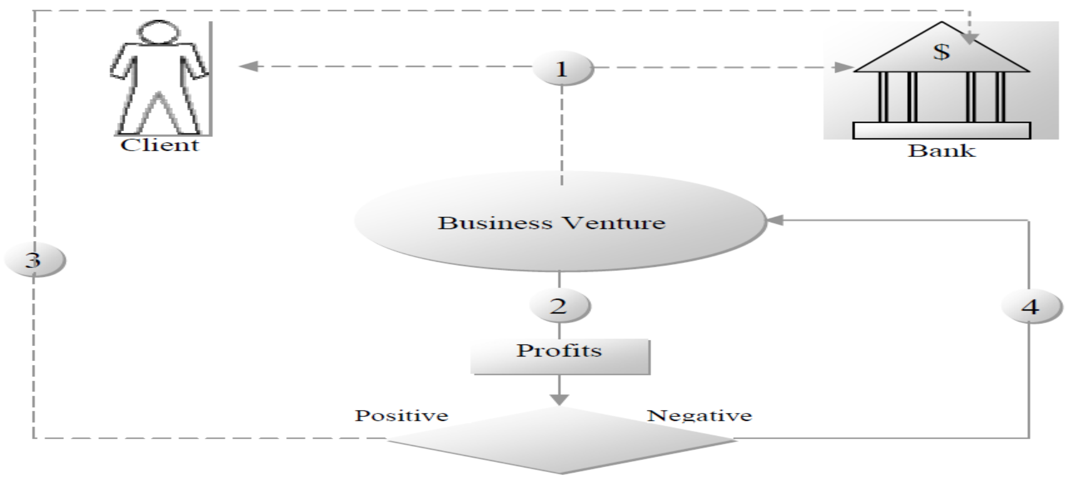

Figure 1: Musharakat Project financing structure

Source: (Obaidullah, 2005)

It is important to note that *Sukuk* certificates are tradable and are either asset-backed or asset-based, making such investments safe. The greatest beneficiaries from a successful application of Islamic project finance to PPPs in SSA will be the millions of people who are forced to drink untreated water (Scanlon et al., 2016), millions of children who die before their 5th birthday due to water-borne diseases (WHO, 2016), millions of farmers whose products perish due to lack of good roads to transport them to urban centres where they are needed (Naudé & Matthee, 2007), millions of car owners who spend fortunes on car maintenance every year due to bad roads (Teravaninthorn & Raballand, 2008), hundreds of families who die from inhaling toxic fumes from electricity generators due to poor supply from the grid (Eberhard & Von Horen, 1995). Some notable projects that were financed using Islamic finance instruments include:

1. Burj al-Arab - Dubai
2. Maconda park apartments-United States
3. The International Finance Facility for Immunisation-UK
4. Doraleh Container Terminal-Djibouti
5. Bibiyana power plant-Bangladesh
6. Konya hospital-Turkey
7. F1 International Circuit – Bahrain

4.2. CHALLENGES TO ISLAMIC PROJECT FINANCE ADOPTION IN SSA

The use of Islamic project finance for infrastructure projects has been very limited within SSA despite its obvious advantages due to a combination of many complex issues in the region. Some of the challenges include lack of awareness by policy makers in the region, poor marketing by IFIs (Bendjilali & Khan, 1995), market domination by the 'big four' consultants relied upon by SSA countries, and the mutual suspicions existing between Muslims and Christians in some SSA countries. In Nigeria for instance, it is the perception of many non-Muslims that using Islamic finance would convert them to Islam despite available evidence to the contrary. Furthermore, PPPs backed by western lenders prefer debt-based financing because higher leverage enables investors achieve higher returns and it is easier to raise debt than equity (Yescombe, 2014). The interest expense on debt is deducted when calculating taxable profit thereby reducing the SPV's tax liability, this treatment is not given to equity. Furthermore, debt has first claim on the SPV's assets, hence carries limited risks while equity entails more risk and is compensated with higher dividends. Secondly, governments usually provide protection for debt than equity, creating an incentive for higher leverage (Ehrhardt & Irwin, 2004). Thirdly, the taxation system discriminates in favour of debt in order to encourage external investments in infrastructure (Ehrhardt & Irwin, 2004). The last challenge facing the adoption of Islamic finance has to do with regulation. Banks' shari'ah boards have been known to give different rulings on the same instrument thereby creating incentives for what has become known as 'fatwa shopping' (Oseni, 2017). A recent example of fatwa shopping is the ongoing Dana Gas fiasco in the UAE where the company is asking the courts to declare its outstanding *sukuk* void for their non-compliance with Islamic Sharia law due to the evolution and continual development of Islamic financial instruments and their interpretation. The High Court in London has ruled against Dana gas insisting that it is obligated to fulfil its covenants to *sukuk* investors. The company has instituted another case in the UAE but a judgement has not been rendered in the case. Industry watchers have observed that if Dana Gas succeeds voiding its sukuk for non-compliance with Sharia law, confidence in sukuk as a financing instrument will be significantly undermined (Billington & Taha, 2018). The shari'ah standards board is working hard on this and many other issues to reduce variability within the Islamic finance regulatory regimes. One way of overcoming these challenges is for SSA governments to adopt well established and less controversial Islamic project finance instruments such as Istisna, Ijarah, Mudarabah, and Musharakah. To further encourage the use of Islamic project financing in SSA, governments can mandate the use of stapled financing mechanism using *Sukuks*. Stapled financing is a pre-arranged financing package for a project developed by the government and provided to bidders during the PPP tender process (World Bank, 2014). SPVs would be permitted to use other financing instruments only if they can prove that it is cheaper and more sustainable than the stapled financing provided by the government.

5. CONCLUSIONS

Sub-Saharan Africa contains the highest number of countries that did not meet the MDGs which expired in 2015. If they are to meet the new SDGs, investments in modern infrastructure using cheap sustainable financing that ensures affordability becomes a priority. However, given the dampening impact of Basel III banking regulations on lending to infrastructure, SSA must seek other sources of financing critical infrastructure. This article has shown that Islamic project finance is a promising financing alternative that is risk-friendly, cheap, and compatible with the ideals underpinning the SDGs. The use of Islamic project finance in PPPs across SSA would lead to increased service affordability, increased value for money and eliminate the need to design tariffs geared towards full cost recovery. Debt-financing has not done SSA countries much good in the last 3 decades, hence the need to try something else. The use of Islamic project finance will broaden the investor base and help diversify any resulting risks, making PPP project failures the exception rather than the norm in SSA. But, SSA governments and built environment professionals must make the efforts towards understanding Islamic financing instruments in order to decide which instrument best suits their needs.

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SIGNIFICANT FACTORS INFLUENCING OPERATIONAL AND MAINTENANCE (O&M) COSTS OF COMMERCIAL BUILDINGS

Devindi Geekiyanage* and Thanuja Ramachandra

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Usually, the costs incurred during the operational phase of a building are much greater than the initial construction cost. Amongst, the running cost of a typical commercial building varies between 70-80% of its total LCC depending on its determinants. However, the significance of those determinants could vary with building function, characteristics of location and economy where it is based. This paper, therefore, investigates the significance of factors influencing the running cost of commercial buildings in Sri Lanka. A questionnaire survey administered to a sample of 125 industry professionals who have more than 10 years of experience in building O&M indicates that O&M costs of a commercial building are influenced by 08 major determinants including building characteristics (BC), maintenance factors (MTF), managerial factors (MNF), environmental factors (EF), political factors (PF), tenant factors (TF), design and & construction defects (DCD), and social factors (SF). The relative significance index (RSI) analysis performed ranked EF as the top determinant influencing both operations and maintenance costs of commercial buildings with an RSI of 0.963 and 0.996 respectively. Further, all the respondents are of the view that building function, occupancy, and building services have a highly significant influence on operations costs whereas natural deterioration, failure to identify the true cause of defect, lack of preventive maintenance, and budget constraints are foremost factors influencing the maintenance costs. The impact of most of the sub-factors except very few namely, building function, age, and location on O&M costs can be controlled up to a greater extent. Thus, early consideration of these factors during the building design and construction will result in reduction of unnecessary costs to be incurred during the operational phase of a building.

Keywords: *Commercial Buildings; Correlation; Determinants; O&M Costs; Relative Significance Index.*

1. INTRODUCTION

Life Cycle Cost (LCC) of a typical building includes capital cost, occupancy and maintenance costs (utility, administrative, building services, replacement costs), and disposal cost. It is observed that the cost incurred during the operational phase of a building project is much greater than its construction or acquisition cost (Flanagan & Jewel, 2008). Most recently, Goh and Sun (2015) found that commercial buildings spend higher running cost than residential, institutional, and industrial buildings. In Wang, Wei and Sun (2014) study, commercial buildings were in the first place with running cost accounting for 70% of the total life-cycle cost.

The running cost of a building could be basically divided into two such as building operational cost and building maintenance cost. This significant growth in operations and maintenance (O&M) costs of buildings are affected by a wide range of factors and the impact of each parameter on the O&M costs vary depending on the building function, geographical characteristics and economy, where the building is located (Ali, 2009). Further, many researchers concluded that these factors have a significant influence on the O&M costs of buildings in developing countries (Kerama 2013; Olayinka and Babatunde 2015; Waziri 2016). Despite, very little attention has been paid to factors affecting O&M costs of commercial buildings, especially, which based in tropics. Therefore, this research investigates the significance of factors influencing the O&M costs of commercial buildings in Sri Lankan tropical climate.

*Corresponding Author: E-mail - d.geekiyanage22@gmail.com

2. FACTORS INFLUENCING THE OPERATIONAL AND MAINTENANCE COST OF BUILDINGS

The literature provides a thorough account of factors affecting the O&M costs of different types of built facilities such as housing, apartments, public buildings, commercial buildings and educational institutions based in different climatic and economic conditions. Accordingly, Ungar (2003) reported 05 factors affecting the operating cost of federal buildings including security requirements, budget constraints, geographical location of buildings, government mandates, and failure to adequately maintain buildings.

Referring to the maintenance cost, most of the investigations carried out are related to developing countries, especially for Nigeria, Malaysia and Kenya due to less attention and budget allocations for building maintenance work (Kerama 2013). For instance, Olayinka and Babatunde (2015) have carried out a study on factors affecting housing maintenance cost in Nigeria and found 20 factors. Out of 20 factors, design and proper workmanship, material specifications, construction supervision, detailing of working drawings, and cash flow analysis have ranked as top 05 factors influencing the housing maintenance cost. Most recently, Waziri (2016) concluded that defective construction materials, poor supervision, defects due to specifications, poor quality control on site, and architectural design defects are top 05 defects influencing the building maintenance cost in Nigeria. In addition, Ali (2009) opined that existing building condition, complaint received regarding building performance, building age, client's request, availability of funding, and Health & Safety (H&S) requirements affect the maintenance cost of buildings in Malaysia respectively. The study further revealed that first two variables have negative moderate correlations with maintenance performance of buildings that are 0.378 and 0.308 respectively. Except above, Kerama (2013) in the study of investigating factors affecting the housing maintenance management cost in Kenya identified 04 determinants including building characteristics, tenant factors, maintenance factors, and political factors. Subsequently, with regard to the commercial building based in Nigeria, Omari (2015) classified these factors into 05 categories such as technical, environmental, management, financial, and social. Besides, El-haram and Horner (2002) study carried out in Scotland divided factors affecting maintenance cost of buildings into 05 groups of variables namely, building characteristics, tenant factors, maintenance factors, political factors, and other factors. Authors further concluded that except building characteristics, high expectation of tenants, budget constraints, misuse of property, right to policy and inability to gain access to the property are key factors contributing to the housing maintenance cost in Scotland. In line with El-haram and Horner (2002), and Ali (2009), Faremi et al. (2015) ranked those factors according to its impact on maintenance cost of tertiary institutions in Nigeria. From the analysis, the age, size of the building, vandalism by users, faulty design and poor incorporation of building services result in dominant factors influencing the cost of maintenance in institutional buildings. Moreover, Ofori1 et al. (2015) have revealed 15 factors influencing the decisions to carry out maintenance works. Amongst, the misuse of building after completion of the construction, faulty design, unavailability of skilled labour, poor financial support for maintenance work, and not using preventive maintenance are the dominant factors influencing the maintenance of housing units in Ghana.

Apart from aforementioned studies, which investigated the factors influencing operational cost and maintenance cost of buildings separately, Perera et al. (2016) concluded that building characteristics, tenant factors, maintenance factors, regulatory and economic factors, and few other factors (Refer Table 1) are highly contributing to the O&M costs of condominiums in Sri Lanka.

Based on the foregoing review, factors influencing the operational cost of buildings can be discussed under 04 major determinants including building characteristics, maintenance factors, managerial factors, and political factors/regulatory requirements while an extensive set of 08 determinants inclusive of environmental factors, tenant factors, design and construction defects, and social factors, affect the cost of maintenance in buildings. Each determinant mentioned above has a range of sub-factors, which contribute to the growing costs of O&M in buildings as illustrated in Table 1.

Despite having enough literature on factors affecting the O&M costs of buildings, none of the studies focused on factors affecting the O&M costs of commercial buildings based in tropical climates particularly, in Sri Lanka. Considering the unique characteristics of building O&M, it is vital to identify the factors affecting these costs individually. For instance, building age has an influential impact on building maintenance cost, where no impact on operational cost (Faremi et al., 2015).

Table 1: Review of Factors Influencing O&M Costs of Buildings

Determinants and Sub-factors	**Sources**									
	Operational cost	**Maintenance cost**								**O&M costs**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Building Characteristics (BC)										
1. Function		X	X							
2. Location	X									X
3. Building age		X	X	X	X	X	X			X
4. Building size		X	X		X		X			X
5. Building height		X	X			X	X			X
6. Type of structure		X	X			X	X			
7. Building materials and components		X	X		X	X	X	X	X	X
8. Building services					X		X			X
9. Finishes		X	X							X
Maintenance Factors (MTF)										
1. Failure to identify the true cause of defect	X					X				
2. Lack of preventive maintenance	X				X			X		
3. Poor workmanship	X	X	X		X		X			X
4. Faulty maintenance	X				X	X				
5. Low concern to future maintenance	X				X	X		X		
6. Failure to execute maintenance at the right time	X	X	X		X					X
Managerial Factors (MNF)										
1. Budget Constraints	X	X	X	X	X	X	X	X		X
2. Lack of building maintenance manuals, standards and specifications					X	X		X	X	
3. Poor quality of spare parts and materials		X	X		X	X	X			X
4. Unavailability of the required spare parts, tools and materials						X				
5. Poor financial control when executing maintenance			X		X	X	X			X
6. Poor or lack of training		X	X		X	X	X			X
7. Poor management by maintenance units		X	X			X	X			X
8. Unqualified and unavailability of maintenance contractors						X		X	X	
9. Unavailability of skilled and educated labours		X				X		X	X	
10. Failure reporting procedure			X		X					X
Design and Construction Defects (DCD)										
1. Poor supervision									X	
2. Architectural design defects					X	X		X	X	X
3. Poor quality control on site					X	X			X	
4. Defective construction materials									X	
5. Poor structural design					X	X		X	X	X
6. Lack of proper reinforcement in concrete									X	
7. Site defects						X		X	X	
Tenant Factors (TF)										
1. Vandalism by tenants		X	X		X	X	X			X

2.	Misuse of property			X			X	X	X		X
3.	Expectation of Tenants			X				X			X
4.	Ignorance about maintenance works						X		X		
5.	Accessibility to the property			X				X			X
	Environmental Factors (EF)										
1.	Natural deterioration										
2.	Harsh climatic conditions						X				X
	Political Factors (PF)										
1.	Changes in legislation (New H&S regulations)	X		X	X			X			X
2.	Changes in O&M standards	X									X
3.	Price inflation	X									X
4.	Changes in taxes and utility tariffs	X									X
	Social Factors (SF)										
1.	Cultural practices						X				
2.	Third-party vandalism			X		X					X

(Source: Adapted from 1-Ungar 2003; 2-Olayinka and Babatunde 2015; 3-El-haram and Horner 2002; 4-Ali 2009; 5-Faremi et al. 2015; 6-Omari 2015; 7-Kerama 2013; 8-Ofori1 et al. 2015; 9-Waziri 2016; 10- Perera et al. 2016)

3. RESEARCH METHODS

A preliminary survey was conducted among six subject experts who have more than 20 years of working experience to confirm the determinants identified through literature review and to develop the conceptual framework for factors influencing O&M costs of buildings as illustrated in Figure 1. Accordingly, 08 determinants together with 48 sub-factors were identified. Finally, a questionnaire survey was carried out among 125 industry professionals who have more than 10 years of experience in building operations and maintenance. The respondents were asked to indicate the extent to which that variables influence the operational cost (24 sub-factors) and maintenance cost (46 sub-factors) of commercial buildings in Sri Lanka, based on a five-point scale where, 1-Highly insignificant, 2-Insignificant, 3-Neither, 4-Significant and 5-Highly significant. A summary profile of survey respondents is presented in Table 2.

Table 2: The Profile of Survey Respondents

Profession	**Designations**	**Number of respondents**		**Work experience**	**Number of respondents**	
		No.	**%**		**No.**	**%**
Engineering	Chief Engineer (8), Facility Engineer (1), Electrical Engineer (17), Supervisors (9)	35	28	Less than 10 yrs.	29	23
Management	Mgr. Admin (8), Facility Mgr. (12), Mgr. Operations (32), Maintenance Managers (28), Service Managers (10)	90	72	10-20 yrs.	77	62
				More than 20 yrs.	19	15
	Total	125	100	**Total**	125	100

As shown in Table 2, most of the respondents are managers (72%) while 35% of the respondents are engineers. Very importantly, all the respondents have working experience in the field of building O&M in commercial buildings in Sri Lanka and the majority (62%) have 10 to 20 years of experience.

For data analysis, initially, a bivariate correlation analysis was conducted to explore the inter-correlation between the determinants of running cost in commercial buildings. The results were presented using the Spearman's correlation coefficient as it is the ideal method to interpret the correlations between ordinal variables, i.e. Likert scale data (Göb et al., 2007). At last, the determinants of O&M costs were prioritized using the Relative Significance Index (RSI) as other researchers such as El-Haram and Horner (2002) and Ali et al. (2010) who had done similar studies have adopted RSI to rank factors. RSI or weight is a type of relative importance analyses, which best fits the purpose of this study. According to Johnson and LeBreton (2004), RSI aids in finding the contribution a particular variable makes to the prediction of a criterion variable both by itself and in combination with other predictor variables. The RSI can be shown in the form of;

$$RII = (\sum W)/(A * N) \quad \text{Eq. (01)}$$

where, W - weighting is given to each statement by the respondents and ranges from 1 to 5; A - higher response integer (5); and N - total number of respondents.

4. RESEARCH FINDINGS AND DISCUSSION

4.1. *FINDINGS OF THE PRELIMINARY SURVEY*

The preliminary survey was conducted among 06 subject experts in order to broaden the scope of determinants to ensure the assessment of O&M costs of commercial buildings fits with the local context. Accordingly, Table 1 developed with the aid of literature findings is modified by altering existing sub-factors and adding new sub-factors as per the expert opinions. All industry experts accepted all the determinants stated are as key variables contributing to the growing O&M costs of commercial buildings in Sri Lanka and they further elaborate the importance of identifying factors affecting building operational cost and building maintenance cost individually.

Accordingly, a conceptual framework for factors influencing the O&M costs of buildings that illustrated in Figure 1 is developed following the important suggestions made by the survey of experts along with the information obtained through the literature review.

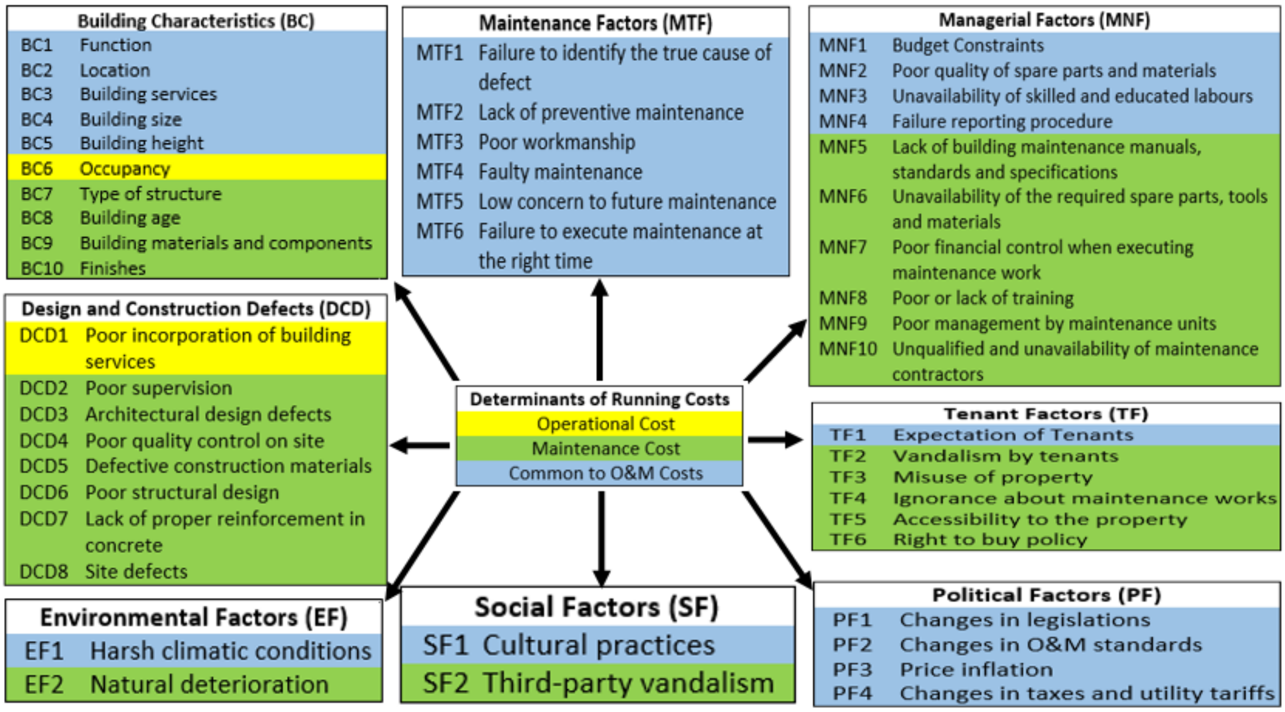

Figure 1: The Conceptual Frameworks for Factors Influencing O&M Costs of Buildings

As shown in the conceptual framework, operational cost of a building is influenced by 08 determinants together with 24 sub-factors, whereas the maintenance cost is affected by the same set of determinants having an extensive set of sub-factors, which is 46. Referring to the operational cost factors, experts highlighted few other variables including the number of occupants, building services, size, height, and function under the building characteristics. In addition, 04 experts elaborate that not only the maintenance cost but also the operational cost of a building is influenced by the poor quality of materials and components, unavailability of skilled and educated building operational staff, and inconsistency of failure reporting procedure, which stated under the managerial factors. Further, the poor incorporation of building services is added to the design and construction defects since it has a significant influence on utility cost of a building. Moreover, all the experts are of the view that expectation of tenants tends to fluctuate the operational cost of a building. For example, the comfort level of a person can be varied from another person thus, the required level of air conditioning, ventilation and lighting may vary incurring severe changes to utility cost consequently, the operational cost. In addition, according to experts, harsh climatic conditions influence the operational cost of a building, especially in high temperature and humid levels, and rainy seasons due to environmental changes. Finally, cultural practices have been identified by 04 experts as a variable influencing the operational cost due to the impact of personal behaviour and clothing etc. However, none of the experts opined new variables to the maintenance cost factors thus, approved the sub-factors found through the literature as it is.

4.2. THE RELATIONSHIP BETWEEN DETERMINANTS OF O&M COSTS OF COMMERCIAL BUILDINGS

In the second stage of analysis, the mean values of determinants were subjected to a correlation analysis in order to explore the relationship between these determinants. The results obtained from the correlation analysis are presented in Table 3.

Table 3: The Correlation of Determinants of O&M Costs in Commercial Buildings

Determinant	Spearman's Correlation Coefficient (The Coefficient of Determination)															
	Operational Cost								Maintenance Cost							
	BC	MTF	MNF	DCD	TF	EF	PF	SF	BC	MTF	MNF	DCD	TF	EF	PF	SF
BC	1.000								1.000							
MTF	0.850** (92%)	1.000							0.047	1.000						
MNF	0.816** (90%)	0.787** (89%)	1.000						0.096	0.304** (55%)	1.000					
DCD	0.372** (61%)	0.224* (47%)	0.190* (44%)	1.000					-0.195* (44%)	0.047	0.142	1.000				
TF	0.372** (61%)	0.224* (47%)	0.190* (44%)	1.000** (100%)	1.000				0.131	0.101	0.037	0.034	1.000			
EF	0.057	0.127	0.138	-0.074	-0.074	1.000			0.136	0.077	0.253** (50%)	-0.020	-0.039	1.000		
PF	-0.091	-0.039	-0.103	-0.016	-0.016	0.000	1.000		-0.024	0.014	0.324** (57%)	-0.002	0.001	0.084	1.000	
SF	0.372** (61%)	0.224* (47%)	0.190* (44%)	1.000** (100%)	1.000** (100%)	-0.074	-0.016	1.000	-0.052	0.253** (50%)	0.354** (59%)	0.057	0.016	0.267** (52%)	0.043	1.000

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

According to the Spearman's correlation coefficients and the significance of correlations at 5% and 1% confidence levels, there are 15 statistically significant and positive correlations including 6 strong, 3 moderate, and 6 weak correlations among the determinants of operational cost in commercial buildings. The analysis further revealed 3 positive moderate correlations, 3 positive weak correlations, and 1 negative weak correlation between the determinants of maintenance cost in commercial buildings. Accordingly, determinants having strong and moderate correlations are discussed in more detail below.

Positive strong correlations

There are 6 positive strong correlations among the determinants of operational cost in commercial buildings. Three out of 6 correlations have resulted in a correlation of 1.000** and they are design and construction defects with tenant factors and social factors, and tenant factors with social factors. This indicates that these variables are 100% intercorrelated with each other thus, 100% of the mean value of one determinant can be explained by the other correlated determinant. Here, the impact of design and construction defects towards the operational cost of a commercial building could be totally controlled by either tenant factors or social factors or vice versa. Further, the behaviour of tenant factors can be 100% predicted by the behaviour of social factors. For example, if the building is designed and constructed as per the expectation of tenants, it could mitigate the impact of cultural practices on operational cost. However, most of the experts in the field of statistical analysis are of the view that these statistics do not reflect the exact behaviour of variables thus, cannot expect a 100% intercorrelation between covariables in practice. In addition, building characteristics has positive strong inter-correlation with maintenance factors (0.850**), and managerial factors (0.816**) under operational cost category. According to the determination of coefficients (R2), 72% and 67% of the mean value of building characteristics can be expressed by maintenance factors and managerial factors respectively or vice versa. Moreover, the maintenance factors and managerial factors are positively and strongly correlated (0.787**) with each other indicating that there is a direct influence in-between these two variables. For example, if it is able to reduce the impact of managerial factors such as the use of poor quality spare parts and number of unskilled labours by providing required training, poor workmanship, lack of preventive maintenance, and faulty maintenance can be reduced, which come under the maintenance factors.

Positive moderate correlations

There are 3 positive moderate correlations among the determinants of operational cost in commercial buildings, which have resulted in R of 0.372** and R2 of 14%. They are building characteristic with design and construction defects, tenant factors, and social factors. Accordingly, only 14% of the mean impact of building characteristics upon the operational cost could be directly explained by either design and construction defects or tenant factors, or social factors. For instance, reduction of improper incorporation of building services could lead to reduce the utility cost incurred by building services and ultimately reduce the cost of building operations. Referring to the maintenance cost of commercial buildings, 3 positive moderate correlations have been found. The maintenance factors have an R equals to 0.304** with managerial factors and only 09% of the mean impact of maintenance factors could be predicted by managerial factors and vice versa. Furthermore, the managerial factors have a positive moderate correlation with political factors (0.354**) and social factors (0.324**). The ideal example to explain the relationship between managerial factors and political factors is the relationship between the proper use of manuals, standards and specifications for building maintenance, and changes introduced to building O&M standards by the government. If further described, the government and regulatory bodies issue updated building O&M standards time to time and building users need to comply with those standards while performing maintenance work of buildings consequently, reduce the impact of those two factors towards the maintenance cost of commercial buildings. Similarly, the behaviour of social factors such as third-party vandalism can be controlled by the proper management of maintenance units, which belongs to the managerial factors.

4.3. KEY FACTORS CONTRIBUTING TO THE O&M COSTS OF COMMERCIAL BUILDINGS

At last, an RSI analysis was conducted to explore the relative significance of factors influencing O&M costs of commercial buildings. Twenty-four sub-factors affecting the operational cost and 46 sub-factors affecting the maintenance cost of buildings, which found from the literature analysis and preliminary survey were approved by the respondents to the context of commercial buildings in different levels of significance. Accordingly, the relative significance of factors affecting operational cost and maintenance cost of commercial buildings are presented in Table 4 together with RSI value and stacked bar charts.

Table 4: The Relative Significance of Factors Affecting Operational & Maintenance Costs of Commercial Buildings

Table 4: The Relative Significance of Factors Affecting Operational & Maintenance Costs of Commercial Buildings

Operational Cost

Code	Sub-factor	RSI
EF	**Environmental Factors**	**0.963**
EF1	Harsh climatic conditions	0.963
PF	**Political Factors**	**0.962**
PF3	Price inflation	0.974
PF4	Changes in taxes and utility tariffs	0.965
PF2	Changes in O&M standards	0.963
PF1	Health and safety regulations	0.944
BC	**Building Characteristics**	**0.960**
BC1	Function	1.000
BC6	Occupancy	1.000
BC3	Building services	1.000
BC4	Building size	0.971
BC5	Building height	0.942
BC2	Location	0.845
DCD	**Design & Construction Defects**	**0.942**
DCD1	Poor incorporation of building services	0.942
TF	**Tenant Factors**	**0.942**
TF1	Expectation of Tenants	0.942
SF	**Social Factors**	**0.942**
SF1	Cultural practices	0.942
MTF	**Maintenance Factors**	**0.852**
MTF4	Faulty maintenance	0.942
MTF2	Lack of preventive maintenance	0.922
MTF1	Failure to identify the true cause of defect	0.847
MTF5	Low concern to future maintenance	0.845
MTF6	Failure to execute maintenance at the right time	0.840
MTF3	Poor workmanship	0.713
MNF	**Managerial Factors**	**0.824**
MNF3	Unavailability of skilled and educated labours	0.942
MNF2	Poor quality of spare parts and materials	0.845
MNF4	Failure reporting	0.845
MNF1	Budget requirement	0.662

Maintenance cost

Code	Sub-factor	RSI
EF	**Environmental Factors**	**0.996**
EF2	Natural deterioration	1.000
EF1	Harsh climatic conditions	0.992
MTF	**Maintenance Factors**	**0.988**
MTF1	Failure to identify the true cause of defect	1.000
MTF4	Faulty maintenance	0.984
MTF6	Failure to execute maintenance at the right time	0.978
MTF2	Lack of preventive maintenance	1.000
MTF3	Poor workmanship	0.984
MTF5	Low concern to future maintenance	0.982
MNF	**Managerial Factors**	**0.966**
MNF1	Budget constraints	1.000
MNF5	Lack of building maintenance manuals standards	0.995
MNF2	Poor quality of spare parts and materials	0.989
MNF6	Unavailability of the required spare parts tools and materials	0.971
MNF7	Poor financial control when executing maintenance work	0.971
MNF8	Poor or lack of training	0.968
MNF9	Poor management by maintenance units	0.957
MNF10	Unqualified and unavailability of maintenance contractors	0.954
MNF3	Unavailability of skilled and educated labours	0.928
MNF4	Failure reporting	0.925
DCD	**Design & Construction Defects**	**0.920**
DCD2	Poor supervision	0.974
DCD3	Architectural design defects	0.971
DCD4	Poor quality control on site	0.946
DCD5	Defective construction materials	0.930
DCD6	Poor structural design	0.918
DCD7	Lack of proper reinforcement	0.912
DCD8	Site defects	0.787
BC	**Building Characteristics**	**0.891**
BC8	Building age	1.000
BC3	Building services	1.000
BC4	Building size	0.973
BC9	Building materials and components	0.957
BC1	Function	0.942
BC5	Building height	0.936
BC7	Type of structure	0.915
BC2	Location	0.842
BC10	Finishes	0.453
TF	**Tenant Factors**	**0.883**
TF2	Vandalism by tenants	1.000

TF3	Misuse of property	1.000
TF1	Expectation of Tenants	1.000
TF4	Lack of understanding the importance of maintenance work	0.955
TF6	Existence of buy policy	0.595
TF5	Accessibility to the property	0.746
SF	**Social Factors**	**0.886**
SF2	Third party vandalism	0.948
SF1	Cultural practices	0.824
PF	**Political Factors**	**0.730**
PF4	Changes in taxes and utility tariffs	0.200
PF2	Changes in O&M standards	0.963
PF1	Health and safety regulations	0.944
PF3	Price inflation	0.814

As shown in Table 4, foremost determinants affecting operational costs are environmental factors (0.963), political factors (0.962), and building characteristics (0.960) respectively. Further, top 03 factors influencing the operational cost of commercial buildings are the function of buildings (1.00), the number of occupants (1.00), and building services (1.00), which gathered under the building characteristics. The function of a building refers to the core business inside the building. The operational cost of a building could vary depending on its function such as commercial, industry, educational and residential etc. As opined by experts during the preliminary survey, "it is apparent that the operational cost of a building may increase with the increase of occupants". For example, the energy required for space cooling and lighting is directly influenced by the number of occupants thus, increase the utility cost, which is a significant operational cost component. According to Ali et al. (2010), the maintenance cost of building services is relatively high as it covers 20-45% of the total building running cost. Next, political factors including price inflation (0.974), changes to taxes and utility tariffs (0.965), and changes in O&M standards 0.963 are key parameters of operational cost in commercial buildings. In Sri Lanka, several legislations and Acts have been introduced relating to the building operations and the implementation of those have become a key concern and legal requirement, particularly in commercial buildings. Few illustrations are as the National Environmental (Municipal Solid Waste) Regulations (No. 1 of 2009) and the Protection of The Rights of Persons with Disabilities Act (No. 28 of 1996). Further, the implementation of CIDA fire regulations is a mandatory requirement for all buildings over 30 meters. And also, the influence of new H&S regulations on building operational cost has been previously elaborated by Ungar (2003). Further, the harsh climatic conditions (0.963) influence the operational cost of commercial buildings. Changes in the climate vary the operational cost throughout the year due to human sensitive environmental changes. For example, the cost of air conditioning may increase with the increase of temperature levels compared to rainy seasons.

Referring to the maintenance cost of commercial buildings, environmental factors (0.996), maintenance factors (0.988), and managerial factors (0.966) are the top determinants respectively. Amongst all sub-factors, 09 including natural deterioration, failure to identify the true cause of defect, lack of preventive maintenance, budget constraints, building age, building services, vandalism by tenants, misuse of property, and expectation of tenants have been resulted with a RSI=1.00 indicating that all respondents are of the view that these factors have a highly significant impact on maintenance cost of commercial buildings. Deterioration of a building can occur either as natural or forced. Natural deterioration defines as physical wear that occurs even though the building is used and maintained properly. It could be occurring due to various reasons basically, continuous usage of building and exposure to the normal environment. The speed or frequency of natural deterioration can be reduced only by way of enhancing the inherent reliability of building. Further, if it is failed to detect the true cause of the defect that could be ended up with unnecessary corrective actions incurring an unnecessary cost for maintenance, where the defect still remains for seeking required maintenance. In addition, not practicing strategic maintenance methods such as preventive and predictive lead to excessive maintenance work and increase the breakdown time and labour cost, which ultimately result in decreased productivity. As Sri Lanka is a country, which has a developing economy, the insufficient fund has become a key issue in many aspects. This has found most commonly in other developing countries such as Nigeria, Kenya and Malaysia due to less attention and budget allocations for building maintenance work (Olayinka and Babatunde, 2015; Omari, 2015; Kerama, 2013). It is apparent that any property deteriorates as it is aged thus, required necessary maintenance to upgrade its quality in many aspects, i.e. for buildings, in performance, safety and market value. The positive relationship between building age and maintenance cost has been previously confirmed by Faremi et al. (2015). Moreover, building services, which gives the life to a building structure have its immense impact on building maintenance. For example, a building cannot be converted to a place where humans can be occupied, i.e. office, at least without key building services such as plumbing, electricity, telecommunication, housekeeping and security etc. Thus, the proper maintenance of these building services directly affects the performance of the building and smooth functioning of the building operations although it incurs a significant share of the total building maintenance cost. At last, the demand made by tenants for a better lifestyle or a living environment is rapidly increasing. This phenomenon has led to the need for maintenance and a corresponding rise in O&M costs (Perera et al., 2016).

5. CONCLUSIONS AND RECOMMENDATIONS

Although both operational cost and maintenance cost belongs to the running cost, factors affecting the costs of building O&M could be varied. Initially, a conceptual framework was developed for the factors influencing O&M costs of buildings and it reveals that the O&M costs of commercial buildings are influenced by 08 determinants namely, building characteristics, maintenance factors, managerial factors, design and construction defects, tenant factors, environmental factors, political factors, and social factors. Further, there are statistically significant inter-correlations between most of the determinants thus, the reduction or elimination of bad impacts of one particular determinant can lead to control the severe influence of the correlated variable on building operational or maintenance cost. Further, giving attention to the relative significance of factors contributing to the building O&M costs, environmental factors, maintenance factors, managerial factors, political factors, and building characteristics may cause a significant impact on O&M costs of commercial buildings in tropics. With reference to the data analysis, most of these factors are controllable to a greater extent except to a very few such as building age, function and location. For example, building characteristics have a significant impact upon both operational cost and maintenance cost and optimization of these characteristics at the pre-construction stage of buildings can lead to minimizing the costs to be incurred during the operational phase of buildings. Finally, it is necessary to conclude that O&M costs have to be given proper consideration at the initial stages of the project itself.

6. ACKNOWLEDGEMENT

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SOLAR NET ZERO ENERGY BUILDINGS: A REVIEW

I.P. Udayanga, S.D.A. Soorige* and N.H.C. Manjula

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Commercial and residential buildings account for almost 40% of the world total energy demand. In order to fulfil that energy requirement, large amount of fossil fuels are used and it has made a greater impact on the environmental sustainability and the economic stability of the society. Therefore, the industry gives more concern to create an environmentally friendly and economically viable renewable energy (RE) solution since last few decades. A number of environmentally friendly building design concepts have been established to promote the renewable energy (RE) usage in the building sector. Solar Net Zero Energy Building (Solar NZEB) can be identified as one such environmental friendly building design concept which has gained a significant global attention in the last decade. This study is focussed on reviewing the Solar NZEB concept and its applicability based on the literature. First the approaches to achieve zero energy balance in a building is explained in terms of energy efficiency measures and onsite renewable energy sources. Further, the design considerations of Solar Net Zero Energy Buildings are identified and following identification of the enablers and barriers for the Solar NZEB, the research concludes with a conceptual framework for Solar NZEB.

Keywords: *Enablers and Barriers; Energy Efficiency Measures; Net Zero Energy Building (NZEB); Renewable Energy (RE); Solar Energy.*

1. INTRODUCTION

Cuce *et al.*(2016) revealed that nowadays buildings are accountable for 40% of the total energy consumption of the world. The major part of that (80-90%) is consumed during the operation stage of the buildings and the rest (10-20%) inherent with the construction stage (Ramesh *et al.,* 2010). Since the costs of resources are frequently increasing, the energy efficiency, resource efficiency and the energy cost saving approaches have become vital in present. Maistry and Annegarn (2016) cited that the best possible way to bring down the energy cost of a building is to reduce the energy demand in operational stage and need to discover more potential methods to reduce operational energy in the building. As an energy efficient building approach, the Net Zero Energy Building (NZEB) concept is rapidly growing since last few years in the world and some of the developed countries have included NZEB concept as their main goal of the energy policy as well (Sartori *et al.*, 2012).

Sartori *et al.* (2010) defined the NZEB as "a building with greatly reduced energy demand that can be balanced by an equivalent on-site generation of electricity, or other energy carriers, from renewable sources". According to the ASHRAE (2008), NZEBs produce as much energy from renewable energy sources to balance the consumption on the annual basis. NZEB is a building design concept which is used for both commercial and residential buildings to achieve the great reduction of energy consumption through efficiency gains in a way that total energy requirement of the building get supplied by on-site renewable energy sources (Torcellini *et al.,* 2006 ; Deru and Torcellini, 2007). As per the investigations of Castro-Lacouture and Roper (2009), solar, wind and geothermal can be used as the primary renewable sources in NZEBs. In addition to that, low impact hydro, biofuels and biogas also can be used as renewable energy sources at the site in NZEBs (Carmichael and Managan, 2013; Deng *et al.*, 2014).

*Corresponding Author: E-mail - dumindu.soorige@gmail.com

Athienitis *et al.* (2010) specified that solar power is the most promising RE solution for the NZEBs to fulfil the energy requirements while reducing the environmental impact. Use of other primary RE sources like wind power for NZEBs are limited due to different wind directions, noises and structural considerations (Torcellini *et al.,* 2006). NZEBs can use the solar energy both in form of electricity and heat which produced by solar PV (photovoltaic) modules and thermal collectors (Good *et al.,* 2015). According to the Department of Energy (2015), there are numbers of benefits are incorporated with the zero energy buildings in the global context which enable the NZEB concept in the world including technical, environmental and social enablers. Nevertheless, some of the barriers are decelerated the growth of NZEB concept and need to find proper solutions to overcome those barriers. This research paper is aimed to develop a literature based framework for the implementation of solar NZEB. In achieving that aim literature review was carried out mainly in the areas such as energy efficiency measures to achieve NZE, Renewable Energy potentials in NZEBs, design considerations of solar NZEB, Enablers of Solar NZEB and Barriers to Solar NZEB. The literature review started with the general NZEB and then gradually narrowed down to the solar NZEB since the solar is the most potential renewable energy source in buildings as per the literature.

2. LITERATURE REVIEW

2.1. *CONCEPT OF NET ZERO ENERGY BUILDING (NZEB)*

As cited by Sartori *et al.* (2012), NZEB is a building which has a great reduction of energy demand that can be balanced by on-site energy generation using renewable energy sources (Sartori *et al.*, 2012). Similarly, Hyde *et al.* (2012) stated that NZEB approach is comprised of building energy demand reduction using energy efficient techniques and increase energy supply through renewable sources like solar energy. According to Torcellini *et al.* (2006), there are four types of NZEB approaches which are commonly used in the world including, Net Zero Site Energy, Net Zero Source Energy, Net Zero Cost Energy and Net Zero Emission Energy. Each type of NZEB uses the grid for exchanging energy and has diverse applications of renewable energy sources.

2.2. *APPROACH OF ZERO ENERGY BALANCE*

A study by Jadhav (2015), zero energy balance of a building can be obtained by mainly 3 steps includes on site demand management, on site supply options and off site supply options. Similarly, Pless and Torcellini (2010) have developed this hierarchy to address the approach of achieving NZE status which is illustrated in Figure 1. First, it is focused to reduce the energy demand and then generate the balance energy demand through RE supply options.

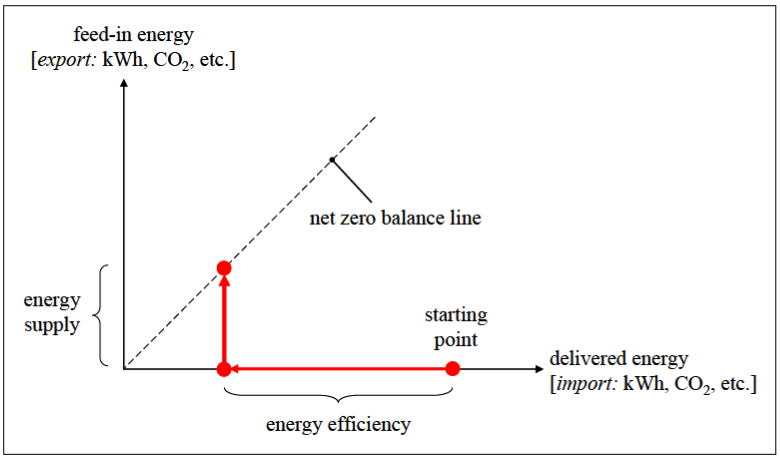

Figure 1: Method of Achieving NZE Status in Buildings

Source: (Sartori et al., 2010)

Here, starting point indicates the energy demand of building which is built according to the minimum requirements of building codes. The first step is to reduce energy demand through energy efficiency techniques (y-axis). Then feed the balance demand using renewable sources (x-axis).

2.2.1. USE OF ENERGY EFFICIENCY MEASURES

According to a study by Pless and Torcellini (2010), reduce the site energy using energy efficiency measures and building technologies is the first step of the NZE concept. There is a great potential for building energy saving through effective operation even without changing the structure of the building (Guan *et al.,* 2010). Further, nowadays energy saving potentials and energy efficiency measures have become top research topics in the world. There are numbers of factors may affect for the performance of NZEBs including form of the building structure, envelope, construction materials, location, orientation, climate changes and proper ventilation of the building (Russell *et al.,* 2008; Chan *et al*., 2010 and Liu *et al.*, 2013). Table 1 presents the energy efficiency measures available as per the literature.

Table 1: Energy Efficiency Measures in Buildings

Energy Efficiency Measures		
1	High efficient HVAC system	(Hyde *et al.*, 2012), (Jadhav, 2015), (Kneifel, 2010)
2	Natural ventilation	(Patil *et al*., 2015), (Hyde *et al.*, 2012), (AlAjmi *et al.,* 2016), (Jadhav, 2015), (Russell *et al*., 2008)
3	Thermal insulation	(Pless and Torcellini, 2009), (Jadhav, 2015), (Banerjee, 2015), (Cellura *et al.,* 2014), (Kneifel, 2010)
4	Evaporative cooling	(Hyde *et al.*, 2012), (Pless and Torcellini, 2009)
5	Ground source heat/cool pumps	(Pless and Torcellini, 2009), (Jadhav, 2015), (Banerjee, 2015), (Russell *et al.,* 2008), (Cellura *et al.*, 2014),
6	Ocean water cooling	(Pless and Torcellini, 2009)
7	Shading on windows	(Hyde *et al.,* 2012), (AlAjmi *et al.,* 2016), (Deng *et al.*, 2014), (Banerjee, 2015), (Aelenei and Gonçalves, 2014), (Cellura *et al.,* 2014), (Kneifel, 2010)
8	High performance glazing and windows	(Hyde *et al.,* 2012), (AlAjmi *et al.,* 2016), (Jadhav, 2015), (Banerjee, 2015), (Cellura *et al.,* 2014), (Kneifel, 2010)
9	Proper orientation of the building	(Deng *et al.*, 2014), (Russell *et al.,* 2008)
10	Energy efficient lighting	(Deng *et al.,* 2014), (Russell *et al.*, 2008)
11	Natural day lighting	(Patil *et al.,* 2015), (Hyde *et al.*, 2012), (AlAjmi *et al.*, 2016), (Pless and Torcellini, 2009), (Jadhav, 2015), (Banerjee, 2015), (Russell *et al.*, 2008), (Aelenei and Gonçalves, 2014), (Kneifel, 2010)
12	Motion sensitive lighting system	(Hyde *et al.,* 2012)
13	Equipment zoning and scheduling	(AlAjmi *et al.*, 2016), (Cellura *et al.,* 2014)
14	Energy Management System (EMS)	(Hyde *et al.*, 2012), (Deng *et al.,* 2014)
15	Building automated systems	(Jadhav, 2015), (Banerjee, 2015), (Russell *et al.,* 2008), (Cellura *et al.*, 2014)

2.2.2. ON-SITE RENEWABLE ENERGY GENERATION

In a net zero energy building (NZEB), the total energy demand of the building is fulfilled by renewable energy which is generated on-site. NZEB supply options are included with solar PV, solar hot water, wind, hydro power and biofuels (Pless & Torcellini, 2009). Classification of the onsite renewable energy sources is given in Table 2.

Table 2: Renewable Energy Potentials in NZEBs

Renewable Energy Sources		
1	Solar PV	(Patil *et al.*, 2015), (Hyde *et al.,* 2012), (AlAjmi *et al.,* 2016), (Pless and Torcellini, 2009), (Deng *et al.,* 2014), (Jadhav, 2015), (Banerjee, 2015), (Russell *et al.,* 2008), (Aelenei and Gonçalves, 2014), (Cellura *et al.*, 2014)
2	Solar thermal	(Patil *et al.*, 2015), (Hyde *et al.,* 2012), (AlAjmi *et al.*, 2016), (Pless & Torcellini, 2009), (Jadhav, 2015), (Banerjee, 2015), (Russell *et al.,* 2008), (Aelenei and Gonçalves, 2014), (Cellura *et al.,* 2014)
3	Wind power	(Patil *et al.,* 2015), (Hyde *et al.,* 2012), (AlAjmi *et al.,* 2016), (Pless and Torcellini, 2009), (Deng *et al.,* 2014), (Jadhav, 2015), (Russell *et al.,* 2008)
4	Low impact hydro	(Patil *et al.,* 2015), (Pless and Torcellini, 2009), (Marszal *et al., 2*011)
5	Biomass	(Hyde *et al.,* 2012), (Pless and Torcellini, 2009), (Deng *et al.,* 2014),
6	Biodiesel	(Pless and Torcellini, 2009), (Russell *et al.,* 2008)
7	Biogas	(Deng *et al.,* 2014), (Marszal *et al.,* 2012)

2.3. SOLAR ENERGY AS A SOLUTION FOR NZEB

As per the study by Kalogirou (2004) identified that in past century the fossil fuels provided the larger portion of energy supply as it is much cheaper than renewable energy sources while giving less concern for environmental pollution. Since, the requirement of a reliable alternative renewable energy source became a crucial concern in last few decades due to the environmental issues, climate changes and global warming as a result of growing energy demand (Mekhilef *et al.,* 2011). Many researchers were discussed on the potential of solar energy solutions as one of the best RE approach (Patil *et al., 2*015; Russell *et al*., 2008). As Kalogirou (2004) further mentioned that, solar energy is more suitable than the other renewable solutions as it supplies clean and pollution-free energy. Singh (2013) stated that solar energy can be used basically in two ways; solar thermal and solar electricity; Solar thermal energy can be directly used to heat water to supply hot water for residential purposes and the light energy of solar can be converted to electricity using solar photovoltaic cells. Integration of solar PV in buildings mainly can be done in two different ways, includes building applied photovoltaic (BAPV) and building integrated photovoltaic (BIPV) (Zomer *et al.*, 2013).

2.4. DESIGN CONSIDERATIONS OF SOLAR NET ZERO ENERGY BUILDINGS

According to the Shi and Chew (2012), there two types of factors to be considered when installing a solar PV system such as geometric conditions and design factors. Geometric conditions include local weather conditions, longitude and latitude and designing factors includes system collection, the orientation of the building, installation area, PV panel area and the tilt angle. Table 3 summarises the design considerations of Solar Net Zero Energy Buildings.

Table 3: Factors to be Considered before Implementing Solar Energy Solutions

Design Considerations		
Geometric conditions		
1	Location of the building	(Shi and Chew, 2012), (Roos, 2009)
2	Solar radiation	(Gomes *et al.,* 2014)
3	Local weather condition	(Shi and Chew, 2012)
4	Altitude and latitude	(Shi and Chew, 2012)
5	Ambient temperature	(Gomes *et al.,* 2014)
Design factors		
6	Building orientation	(Shi and Chew, 2012), (Sun *et al.,* 2012), (Lan *et al.,* 2015), (Roos, 2009)
7	Roof type	(Shi and Chew, 2012), (Roos, 2009)
8	System selection	(Shi and Chew, 2012), (Meral and Dinçer, 2011), (Sun *et al.,* 2012)
9	Install location of PV	(Shi and Chew, 2012), (Roos, 2009)
10	Area of PV	(Shi and Chew, 2012), (Roos, 2009)

Design Considerations		
11	Tilt angle	(Shi and Chew, 2012), (Lan *et al.*, 2015), (Roos, 2009), (Handoyo *et al*., 2013)
12	Shading effect	(Shi and Chew, 2012), (Roos, 2009), (Gomes *et al.,* 2014)
13	Power quality of grid connection	(Meral and Dinçer, 2011)
14	Effect of solar system sub components	(Meral and Dinçer, 2011)

2.5. ENABLERS OF SOLAR NET ZERO ENERGY BUILDING CONCEPT

Zero energy buildings have become popular in last few years since the industry has given more concern on the limitations of the energy supply options and energy sources and the increase of energy cost and environmental impact (Aelenei et al., 2015). As per the literature finding of different authors, some key factors which enable the Solar NZEB in the global context were identified and Table 4 shows the review of the findings.

Table 4: Enablers of Solar Net Zero Energy Buildings

Enablers of Solar Net Zero Energy Buildings		
Technical Enablers		
1	Great reduction of energy demand	(Patil *et al.,* 2015), (Habash *et al.,* 2014), (Sartori *et al.,* 2010), (Lindkvist *et al.*, 2014)
2	Independence energy supply	(Aelenei et al., 2015), (Habash *et al*., 2014)
3	Improve occupant comfort level	(Aelenei *et al*., 2015), (Sartori *et al*., 2010)
Economic Enablers		
4	Less energy cost	(Aelenei *et al.*, 2015), (Deng *et al.*, 2014), (Lindkvist *et al., 2014)*, (Patil *et al*., 2015)
5	Earn profit through excess energy generation	(Jadhav, 2015)
Organizational Enablers		
6	Reduce carbon footprint	(Jadhav, 2015)
7	Increase the reputation of organization	(ASHRAE, 2008)
8	Increase business opportunities	(Koo *et al.,* 2014)
Political and Administrative Enablers		
9	Government policies	(Sartori *et al.,* 2010)
10	Tax deductions	(Aelenei *et al*., 2015)
11	Low interest loans by government	(Aelenei *et al*., 2015)
Environmental Enablers		
12	Environmental friendly building design	(Sartori *et al*., 2010), (Deng *et al.,* 2014)
13	Promote sustainability	(Sartori *et al.,* 2010)
14	Reduction of GHG emission	(Dean and Turnbull, 2014), (Jadhav, 2015)

2.6. BARRIERS TO SOLAR NET ZERO ENERGY BUILDINGS

There are numbers of barriers to implement solar energy solutions in NZEB both in the residential and commercial sector (Brostrom *et al.,* 2008). However, Lindkvist *et al.* (2014) described that there are five various dimensions which makes a great impact on the implementation of zero energy concept including technical, economic, social, environmental, organizational and legal. According to the literature findings, barriers to Solar NZEB concept were summarized using aforementioned dimensions as shown in Table 5.

Table 5: Barriers to Solar Net Zero Energy Buildings

Barriers to Solar Net Zero Energy Buildings		
Technical Barriers		
1	Inadequate work skills, training and awareness of workers	(Margolis and Zuboy, 2006), (Owen, 2006), (Sovacool *et al., 2011)*, (Aelenei *et al.*, 2015), (Barton, 2003), (Kraljevska, 2014)
2	Lack of innovations	(Lindkvist *et al.,* 2014)

Barriers to Solar Net Zero Energy Buildings		
3	No proper method of performance evaluation and verification	(Aelenei *et al.,* 2015), (Deng *et al.,* 2014)
4	Performance barriers to solar system equipment	(Sovacool *et al.,* 2011), (Brostrom *et al.,* 2008)
5	Building design errors to utilize solar	(Dean and Turnbull, 2014), (Brostrom *et al.,* 2008)
6	Lack technical solutions in maintenance	(Lindkvist *et al.,* 2014)
Economic Barriers		
7	High initial cost	(Margolis and Zuboy, 2006), (Owen, 2006), (Sovacool *et al.*, 2011), (Painuly, 2001), (Kraljevska, 2014), (Marszal *et al.*, 2011), (Brostrom *et al.*, 2008)
8	Uncompetitive market price for solar systems	(Owen, 2006), (Kraljevska, 2014)
9	Lack of financial sources	(Sovacool *et al.,* 2011), (Painuly, 2001), (Aelenei *et al.,* 2015), (Kraljevska, 2014)
10	Long payback period	(Painuly, 2001), (Aelenei *et al.,* 2015), (Kraljevska, 2014)
Socio Cultural Barriers		
11	Inadequate information dissemination	(Margolis and Zuboy, 2006), (Lindkvist *et al.,* 2014)
12	Architectural and cultural values of structures limit the technical solutions	(Lindkvist *et al.,* 2014), (Barton, 2003)
13	Unfamiliarity of society	(Sovacool *et al.,* 2011), (Kraljevska, 2014)
14	Impracticable expectations	(Sovacool *et al.,* 2011)
Political and Administrative Barriers		
15	Deficiency of government policy supporting	(Margolis and Zuboy, 2006), (Sovacool *et al.,* 2011), (Painuly, 2001), (Barton, 2003)
16	Lack of codes and standards	(Margolis and Zuboy, 2006), (Lindkvist *et al.,* 2014), (Brostrom *et al.,* 2008)
17	Poor participation of stakeholders	(Margolis and Zuboy, 2006), (Painuly, 2001)
18	Deficiency of legal and regulatory frameworks	(Painuly, 2001), (Kraljevska, 2014)
Environmental Barriers		
19	Environmental friendly material usage	(Lindkvist *et al.,* 2014)
20	Hazardous free innovations	(Painuly, 2001), (Yuosoff and Kardooni, 2012)

3. THEORETICAL FRAMEWORK FOR SOLAR NZEBS

Theoretical framework for Solar NZEB concept was developed based on the key literature findings as shown in Figure 2. It demonstrates how all the key factors are linked together to gain the ultimate objective of Solar NZEB concept which achieves the zero energy balance in a building using solar energy.

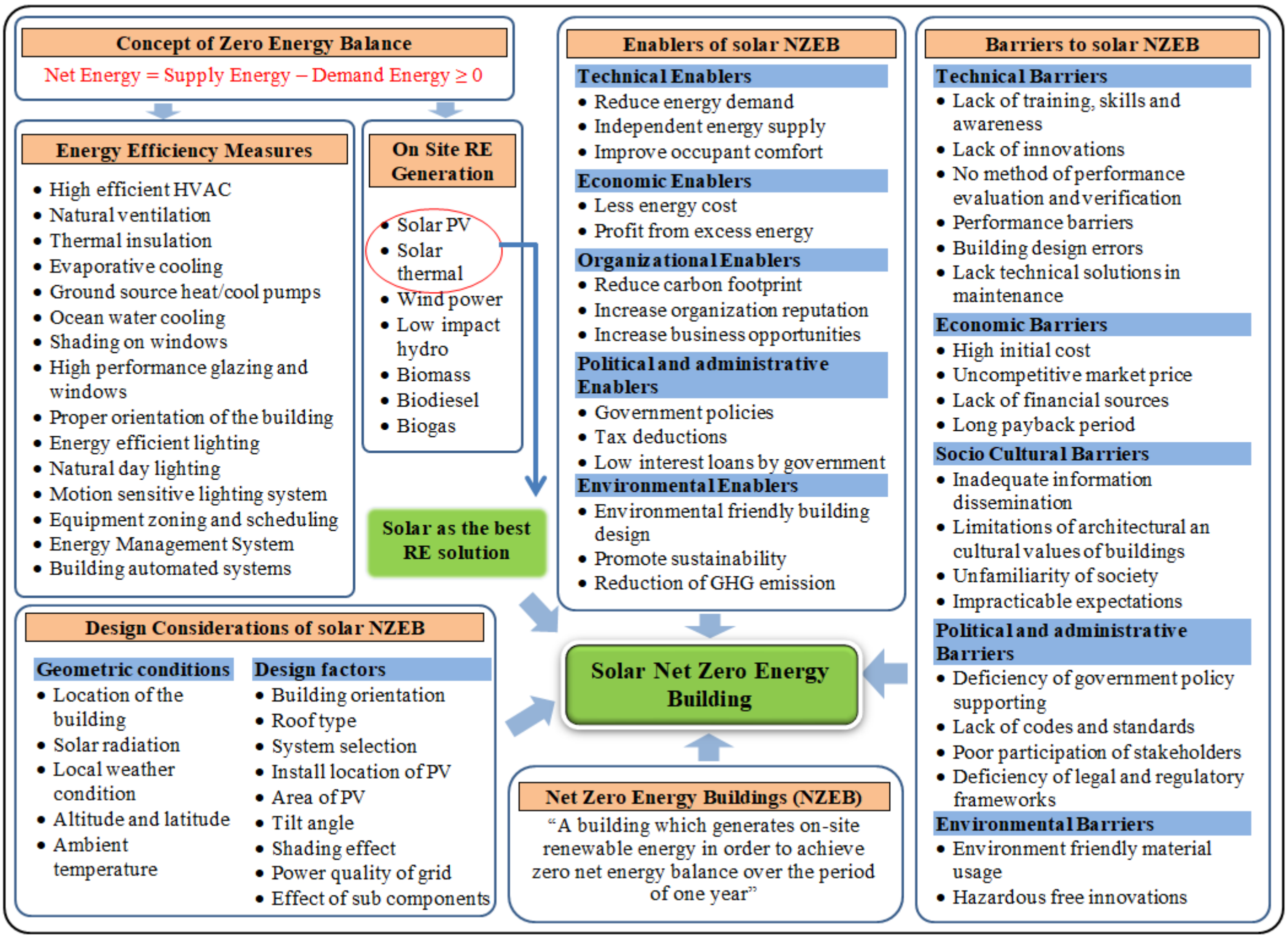

Figure 2: Theoretical Framework for Solar NZEBs

4. Conclusions and Recommendations

The theoretical framework which is shown in Figure 2 illustrates key aspects of Solar NZEB concept and it will assist for the professionals to learn about the concept and researchers for the further researches. The identified enablers and barriers in the global context may vary in different regions and each and every factor may not account the same weight. Hence, it is proposed to carry out further research on evaluating the enablers and barriers for solar NZEB and to develop strategies to overcome barriers considering different contexts.

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STAKEHOLDER MANAGEMENT IN COMPLEX PROJECTS

Tuan Son Nguyen* and Sherif Mohamed

School of Engineering & Built Environment, Griffith University, Gold Coast, Queensland, Australia

ABSTRACT

Effective stakeholder management is a critical success factor for all types of projects. The increasing complexity in construction projects makes the management of project stakeholder management increasingly challenging due to their diverse characteristics, including power, interests and attitudes. It appears that much of the literature has focused on stakeholder management with very limited or no regard to either the level of project complexity or the extent of meeting project success measures. The objective of this paper is, therefore, to fill these research gaps by: (1) critically reviewing relevant literature; (2) briefly presenting key effective stakeholder management strategies; and (3) developing a conceptual framework for empirical testing. The paper provides a concise description of the framework and its constructs, and outlines the proposed methodology for testing its relevant hypotheses.

Keywords: *Complex Projects; Project Success; Stakeholder Management.*

1. INTRODUCTION

Stakeholder management (SM) is a key factor affecting project performance in complex projects (CPs) (Beringer et al., 2012). SM considers not only individual stakeholders but also how stakeholders influence one another in complex interactions (Beringer et al., 2012); stakeholder interrelationships are themselves a cause of project complexity (Yang, 2014).

It is widely recognised in the literature that many projects fail (Damoah and Akwei, 2017). There are many causes of failure, one of which is project complexity, which creates difficulty in completing projects and requires extra effort to overcome (Dao et al., 2016). CPs demand systematic approaches and efficient management skills in managing stakeholders to attain the best outcomes in terms of project performance (Mok et al., 2015).

The literature demonstrates that stakeholder characteristics play a critical role in effective SM, as project managers select appropriate SM strategies to deal with issues arising from specific stakeholder characteristics. Clear project objectives, agile response to change and effective communication are important components of an effective SM framework in mega-construction CPs (Park et al., 2017). A complex mega-construction project requires a more specialised approach to manage stakeholders (Park et al., 2017). Also, the uncertain and complex nature of mega-construction projects requires an effective stakeholder management approach to resolve conflicting stakeholder interests (Mok et al., 2015).

An investigation into SM in CPs is necessary (Nguyen et al., 2018). In particular, research into the relationship between stakeholder characteristics and perceived project success in CPs, as well as the mediating effects of effective SM (including having clear project objectives, agile response to change and effective communication) on the relationship between stakeholder characteristics and perceived project success in CPs, is of vital importance. Therefore, the objective of this paper is to 1) critically review the relevant literature, 2) briefly present the key effective SM strategies, and 3) develop a conceptual framework for empirical testing. Figure 1 depicts the initial research model for this study.

*Corresponding Author: E-mail – tuanson.nguyen@griffithuni.edu.au

Specifically, this research is guided by the following questions:

- What is the relationship between stakeholder characteristics and perceived project success in CPs?
- How does effective stakeholder management mediate the relationship between stakeholder characteristics and perceived project success in CPs?

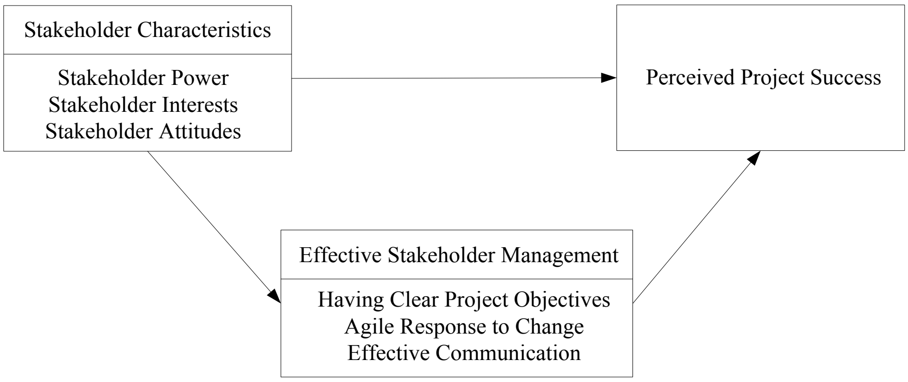

Figure 1: Initial Research Model

2. LITERATURE REVIEW

Literature reviews support researchers to better understand the research topic, and assist in identifying the boundaries of the current body of knowledge and research trends and shaping future research. This section analyses the latest research developments on stakeholder characteristics and effective SM in the context of CPs. Findings on project complexity and project success, as relevant to the research topic, are also discussed.

2.1. STAKEHOLDER CHARACTERISTICS

This sub-section discusses three stakeholder characteristics, namely stakeholder power, stakeholder interests and stakeholder attitudes.

2.1.1. STAKEHOLDER POWER

Stakeholder power can be defined as 'the ability of those who possess power to bring about the outcomes they desire' (Salancik and Pfeffer, 1974). Etzioni (1964) proposed three types of power: coercive power, based on physical resources such as force, violence or threats (for example, the use of a gun); utilitarian power, based on material or financial resources (for example, possession of goods, services and money); and normative/social power, based on symbolic resources (for example, prestige, esteem, love and acceptance). Power is obtained by supplying or withholding material, financial, symbolic or physical resources (Aaltonen et al., 2015). Power might be increased by gaining political support from local and national authorities (Aaltonen and Sivonen, 2009). According to Freeman and Reed (1983), stakeholders have formal, economic and political power. Parent and Deephouse (2007) noted that power is primary in stakeholder salience and decision-making. In an empirical study of construction projects, Yang et al. (2014) found that stakeholder power is positively and highly correlated with 'compromise' and 'adaptation' strategies - if stakeholders have high levels of power, managers should apply gentle strategies. Therefore, stakeholder power in a project can be seen as the ability to affect the implementation and/or outcomes of the project.

Power is one of the main stakeholder characteristics used to classify stakeholders. It is an important characteristic in the stakeholder salience model and stakeholder matrices. The stakeholder salience model was proposed by Mitchell et al. (1997) for characterising and classifying stakeholders according to the power, legitimacy and urgency of their claims. This model provides managers with a vital tool to determine the degree and type of attention stakeholders should receive from management (Mitchell et al., 1997). This approach is helpful in identifying stakeholder influence on project decision-making in global projects (Aaltonen et al., 2008), as stakeholders have differing levels of influence over decision-making processes and project phases (Herazo & Lizarralde, 2016). The stakeholder salience model has been applied to identify stakeholder attributes. Herazo and Lizarralde (2016) used stakeholder salience to identify stakeholder attributes in the planning and execution phases of a sustainable building project, while Aaltonen et al. (2015) applied the stakeholder salience model to propose a salience/position matrix for analysing changes in stakeholders' importance and positions on nuclear projects.

The first stakeholder matrix was the power/dynamism matrix proposed by Mendelow (1981), in which four quadrants were formed by dividing each axis into two portions: high versus low on the power axis and dynamic versus static on the dynamism axis (see Figure 2).

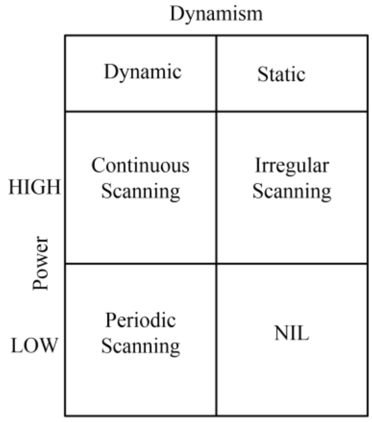

Figure 2: Power Dynamism Matrix (Mendelow, 1981)

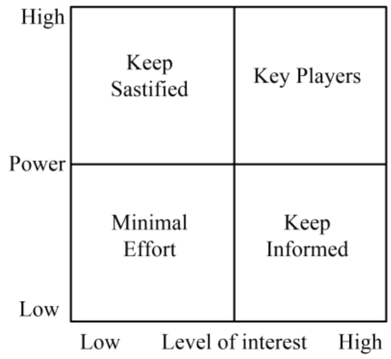

Figure 3: Power/ Interest Matrix (Johnson and Scholes, 1999)

Johnson and Scholes (1999) simplified and adapted the Mendelow (1981) model, proposing a power/interest matrix, in which the interest axis replaced the dynamism axis (see Figure 3). In classifying stakeholders in the power/interest matrix, project managers obtain a better understanding of how communication and relationships among stakeholders affect the project and its operation (Olander & Landin, 2005).

Building on Johnson and Scholes (1999), the power/interest matrix was further modified by Olander and Landin (2005), who developed a scale from 1 to 10 to estimate relative power and stakeholder interest in a project. Pacagnella Júnior et al. (2015) applied Olander and Landin's model to classify and describe the main stakeholders with regard to their power and interest in the implementation of CPs. The stakeholder influences identification matrix was proposed by examining the power and the urgency of stakeholders (De Schepper et al., 2014).

Stakeholder power can be classed into different levels, such as weak, medium and strong power positions (Blokhuis et al., 2012) and none, low, medium and high levels of power (Jepsen & Eskerod, 2009). Luyet et al. (2012) suggested that stakeholders be characterised to understand the power relations between them and their specific interest in projects.

2.1.2. STAKEHOLDER INTERESTS

Stakeholder interests can be defined as the interests of each stakeholder group in impressing its expectations on project decisions (Olander & Landin, 2005), including when, why and how stakeholders are involved or perceived to be involved (Caniato et al., 2014).

Stakeholders have different levels of interest in projects (Yang & Shen, 2014). Understanding stakeholder interests is a critical success factor in construction projects (Yang & Shen, 2014) and CPs (Park et al., 2017). Understanding stakeholder interests, roles and expectations has become a critical topic of analysis and research (Pandi-Perumal et al., 2015), essential for identifying and analysing the positions and interests of stakeholders involved in projects (Elias, 2012). Identifying stakeholders regarding potential interests in projects is an important part of stakeholder analysis (Pan, 2005). Further, the purpose of stakeholder analysis is to indicate whose interests should be taken into consideration in decision-making processes and why (Aaltonen & Sivonen, 2009).

To achieve project success, project managers must be skilled in managing the interests of multi-stakeholders throughout the whole project management process (Sutterfield et al., 2006). Managers must identify the significance and legitimacy of stakeholders and pay attention to, and respond to, stakeholders' interests and concerns (Post et al., 2002).

It is of interest to note that the stakeholder matrix usually concerns two characteristics, for instance, power/interest, influence/interest and power/urgency. In particular, combining power and interest is widely applied (Johnson & Scholes, 1999, Newcombe, 2003, Olander & Landin, 2005, Yang, 2014).

Stakeholder interests can be classed into different levels, based on linguistic terms, such as low to high (Johnson & Scholes, 1999), or via a number scale, such as 1 to 10 (Olander & Landin, 2005).

2.1.3. STAKEHOLDER ATTITUDES

Stakeholder attitudes towards projects can be defined as the perception stakeholders have of the project, be it supportive or non-supportive. Attitude has been used to classify stakeholders into groups. Stakeholder attitude and behaviour are critical factors that influence decision-making strategies and processes (Yang et al., 2014).

The classification model of stakeholder positions proposed by Savage et al. (1991) identifies whether there is potential for cooperation or threat. Stakeholders are classified into four types - supportive, marginal, non-supportive and mixed-blessing - to help managers select generic strategies for managing stakeholders with differing levels of potential for cooperation or threat. The associated SM strategies suggest involving the supportive stakeholder, monitoring the marginal stakeholder and defending against the non-supportive stakeholder. By involving supportive stakeholders in relevant issues, managers can increase stakeholders' cooperative potential. Monitoring helps to manage marginal stakeholders whose potential for both cooperation and threat is low. Non-supportive stakeholders are initially managed best by applying a defensive strategy. Mixed-blessing stakeholders, who rate highly on both potential for cooperation and potential for threat, are best managed through collaboration (Savage et al., 1991). Another classification model, based on stakeholder position on a project, has been proposed by McElroy and Mills (2000). In this model, five levels of stakeholder attitude are presented: active opposition, passive opposition, noncommittal, passive support and active support.

Stakeholder attitude is one of characteristics that Aaltonen et al. (2015) used to develop the salience/position matrix to analyse changes in stakeholders' importance and position on complex nuclear projects. Stakeholders are classified by degree of salience (low versus high) and degree of supportiveness (non-supportive versus supportive). By applying the salience/position model, a manager can recognise stakeholders' power and attitude, providing an understanding of stakeholders and can thus choose an effective SM strategy for each stakeholder group.

Yang (2014) reported on an instance in which stakeholder attitudes towards a project were examined during a project management team workshop. The conclusion was that stakeholders with non-supportive positions and who are highly ranked should take priority, and that project managers tend to engage more with high-priority stakeholders with opposing attitudes (Yang, 2014).

Jepsen and Eskerod (2009) considered positive attitudes towards projects to be a contribution, where contributions take the form of specific deliverables, a positive attitude or a specific behaviour, such as making a supportive decision. Yang et al. (2014) found that there are correlations between stakeholder attitudes (cooperative potential, competitive threat and opposing position) and decision-making strategies in SM in construction projects.

2.2. EFFECTIVE STAKEHOLDER MANAGEMENT

This section discusses three elements of effective stakeholder management strategies; namely (1) having clear project objectives, (2) agile response to change and (3) effective communication.

2.2.1. HAVING CLEAR PROJECT OBJECTIVES

Having clear project objectives are one of five criteria for effective SM in complex mega construction projects (Park et al., 2017). Project managers who clearly understand project objectives perform better in SM. Common goals and strategic flexibility are the two main factors in clear project objectives (Park et al., 2017). A clear definition of the project mission supports stakeholders to understand what should be done and whether their requirements will be met. Setting a target level of stakeholder satisfaction and involvement may help prevent wasting of resources. Alternative options should be prepared to ensure the proper revision of the project mission. Effective strategies bring about different outcomes for persuading stakeholders, while a lack of a clear strategy may lead project managers to apply defensive action (Olander & Landin, 2008).

2.2.2. AGILE RESPONSE TO CHANGE

In the context of CPs, the research trend is to focus on environmental project complexity that involves multiple stakeholders and changes in policy, regulation, technology, economy and nature. Park et al. (2017) found that responding to environmental changes is one of five important agendas for an SM framework for CPs. Responding to political and economic change, responding to policy change and responding to social values change are three components of responding to environmental changes (Park et al., 2017). Managers of CPs should identify potential changes to the project environment, how these changes might affect projects and stakeholders and how to respond appropriately and with agility to these changes (Park et al., 2017).

2.2.3. EFFECTIVE COMMUNICATION

Effective communication and a clear definition of the project are other important factors in the SM framework for CPs (Park et al., 2017). Two-way communication, minimisation of dissatisfaction and active stakeholder participation are the main factors comprising effective communication (Park et al., 2017). Two-way communication includes sharing information with stakeholders, allowing sufficient opportunities to appeal and building trust with stakeholders. Minimisation of dissatisfaction includes compromising to overcome conflicts among stakeholders, keeping balance among stakeholders and reasonable compensation for private loss. Active stakeholder participation includes operating communication system, operating governance system and monitoring, evaluation and feedback.

2.3. *COMPLEX PROJECTS*

CPs have received much attention from researchers and project managers because of an increase in the number of complex projects worldwide across many fields (Floricel et al., 2016), and project failure as a result of this complexity (Vidal et al., 2011). As projects become increasingly complex, there are increasing concerns about the complexity of project concepts and its effect on the project management process (Baccarini, 1996).

Research on project complexity measurement has been conducted for many years. The Crawford-Ishikura seven-factor table for evaluating roles (CIFTER) is one of main project classification methods used by institutions in the project management field (Bosch-Rekveldt, 2011). CIFTER takes into consideration technical project management aspects that broadly focus on the interaction between the project and business environment (Bosch-Rekveldt, 2011). Each of the seven factors is assessed using linguistic terms that relate to scores from 1 to 4. The total score of these factors determines the level of project complexity.

Aitken and Crawford (2007) conducted a study across a broad range of project fields to test CIFTER as a tool for categorising projects with regard to project management complexity. They concluded that CIFTER is a valid instrument for assessing and categorising projects by complexity. There was a positive correlation between the assessments by project managers and independent assessors (Aitken & Crawford, 2007). CIFTER was also applied by Harvett (2013) to evaluate project complexity levels.

For the objectives of this study, CIFTER was selected as an appropriate framework for evaluating CPs. It is part of a global standard that is based on perceptions of project complexity. Practitioners and researchers use this method, and it has been deemed to have a good level of consistency of assessment by project managers and independent assessors.

2.4. *PROJECT SUCCESS*

Criteria for project success are well established, and include time, budget and performance goals (Shenhar et al., 2001). The project management body of knowledge refers to project success in terms of time, cost, scope, quality and customer satisfaction (PMI, 2004) - widely known as the ‘triple constraint’. According to Ika (2009), project success is determined based on completing the project objectives within the constraints of time, cost and quality, plus other project achievements, for instance, meeting the strategic objectives of the client organisation and business success, client satisfaction, advantages for stakeholders and project personnel and other business value achievements. Yang et al. (2011) also suggested using stakeholder satisfaction as a criterion for project success in addition to the traditional measurement of time, cost and quality.

Stakeholders have differing views of success, and these might vary over different timescales (Turner, 2009). Project managers can use critical success factors (CSFs) to identify the necessary factors to meet customer requirements (Bond, 2015). Kerzner (2009) noted that project managers can use both primary and secondary CSFs. Shenhar et al. (2001) extended the notion of project success by adding criteria, such as initial commercial/business success of the products and potential for future business growth.

Time, cost, quality, project objectives and stakeholder satisfaction can all be used as criteria for evaluating project success.

3. RESEARCH METHODOLOGY

This section presents a conceptual research model that will be empirically tested using structural equation modelling (SEM) to determine the role effective SM have on the relationship between stakeholder characteristics and perceive project success in the context of CPs.

3.1. RESEARCH DESIGN

This study is a non-experimental descriptive and correlation research study using SEM to investigate the relationship between stakeholder characteristics and perceived project success, and explore the mediating effects of having clear project objectives, agile responses to change and effective communication on the relationship between stakeholder characteristics and perceived project success in CPs. Figure 4 depicts the conceptual research model for this study.

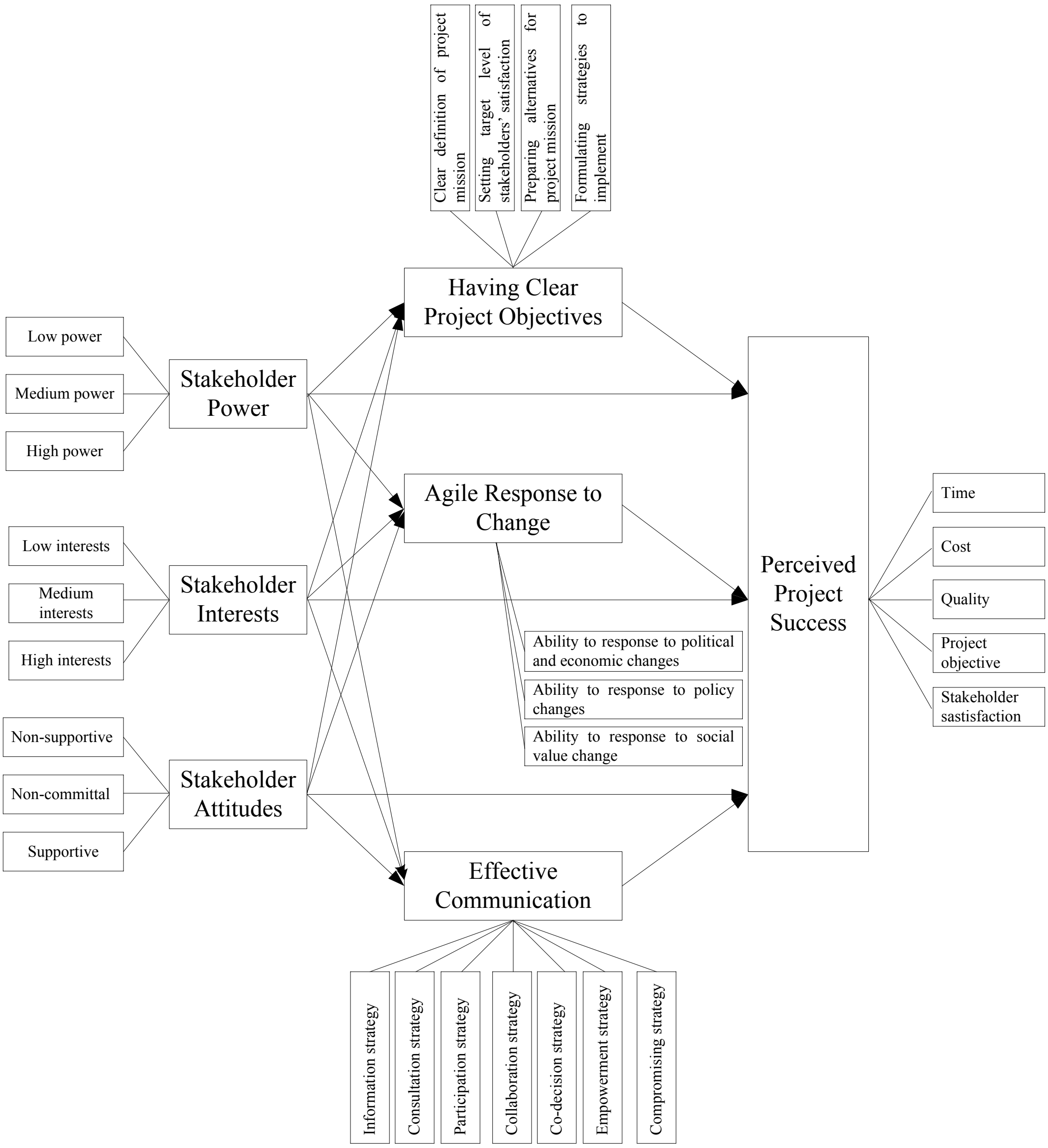

Figure 4: Conceptual Research Model

A research design is a plan that researchers follow to answer research questions as validly, objectively, accurately and economically as possible Kumar (2014). In this study, a quantitative method is selected, as the objective is to test the theory rather than develop it. In quantitative methods, a researcher tests or verifies a theory by examining hypotheses or related questions (Creswell, 2014).

A survey design is applied to collect data capable of providing a quantitative description of trends and opinions of a population by studying a sample of the population to draw inferences (Creswell, 2014). The research population and the target sample for this study consists of project managers based in Australia across various industries. Projects from the survey will be classified based on CIFTER scores. The perceived complexity of projects will be classified into 'low' and 'high'. Only data from the projects that have a high level of project complexity will be used for analysis.

3.2. HYPOTHESIS

Based on the research questions, the following hypotheses are formed:

H1 Stakeholder power negatively affects perceived project success in CPs.

H1a Having clear project objectives enhances the relationship between stakeholder power and perceived project success in CPs.

H1b Agile response to change enhances the relationship between stakeholder power and perceived project success in CPs.

H1c Effective communication enhances the relationship between stakeholder power and perceived project success in CPs.

H2 Stakeholder interests negatively affect perceived project success in CPs.
H2a Having clear project objectives enhances the relationship between stakeholder interests and perceived project success in CPs.
H2b Agile response to change enhances the relationship between stakeholder interests and perceived project success in CPs.
H2c Effective communication enhances the relationship between stakeholder interests and perceived project success in CPs.

H3 Stakeholder attitudes positively affect perceived project success in CPs,
H3a Having clear project objectives enhances the relationship between stakeholder attitudes and perceived project success in CPs.
H3b Agile response to change enhances the relationship between stakeholder attitudes and perceived project success in CPs.
H3c Effective communication enhances the relationship between stakeholder attitudes and perceived project success in CPs.

3.3. RESEARCH TOOLS

SEM is a well-known technique for estimating, analysing and testing models that specify relationships among observed and latent variables (Kline, 2015). It uses different types of models to represent relationships among observed variables, with the basic goal of providing a quantitative test of the theoretical model hypothesised by the researcher (Lomax and Schumacker, 2012). More specifically, different theoretical models that hypothesise how sets of variables are defined as constructs and how these constructs are related to each other can be tested (Lomax and Schumacker, 2012).

The purpose of SEM is to determine the extent to which the theoretical model is supported by sample data. In the case that the sample data support the theoretical model, more complex theoretical models can be hypothesised. However, if the sample data do not support the theoretical model, the original model can be modified and retested, or an alternative model can be developed and tested. In essence, SEM tests theoretical models using the scientific method of hypothesis testing to advance our understanding of the complex relationships among constructs (Lomax and Schumacker, 2012).

There are three main factors supporting the application of SEM in research. First, scholars are becoming more aware of the benefits of using multiple observed variables to better understand their area of scientific inquiry. Second, it involves greater recognition for the validity and reliability of observed scores from measurement instruments. Third, SEM software programs are becoming increasingly user friendly (Lomax and Schumacker, 2012).

In this study, SEM will be applied to statistically analyse the data, test hypotheses and evaluate the model fit.

4. CONCLUSIONS

This research contributes insights into the understanding of the relationship between stakeholder characteristics and perceived project success in the context of CPs. It will present the effects of having clear project objectives, agile response to change and effective stakeholder communication on the relationship between stakeholder characteristics and perceived project success in CPs. The study will contribute to the body of knowledge on SM in CPs. The results of the study might allow for an improvement in project success rates and the effectiveness of SM in the context of CPs.

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STAKEHOLDERS' PERCEPTION ON PROJECT UNCERTAINTY IN PPP PROJECTS IN INDIA

C. Prathapmohan Nair* and Ashwin Mahalingam

BTCM Division, Department of Civil Engineering, Indian Institute of Technology Madras, Chennai, India

ABSTRACT

PPP projects are often complex, unique and dynamic due to high sunk-in costs and long concession period making it vulnerable to risks (known-unknowns) and uncertainties (unknown-unknowns). Previous researches focus on risks associated with PPP projects. But these projects are hit by uncertainties which surfaces as turbulences during the execution as well as the operation stage of the project. The extant literature does not focus much on the uncertainties manifested in these projects nor does it convey the stakeholders' outlook on uncertainties, which has a strong bearing on project management. In order to ensure sustainability of PPP projects, among other factors, it is important to identify uncertainties that affect their performance in various phases or leads to uncertain situations. A superset of uncertainties identified from literature was subsequently expanded and validated by PPP Experts. Stakeholders perceptions on the fifty-four identified uncertainties likely to manifest in various phases was assessed through a survey to identify and evaluate the uncertainties that affect the implementation of transport PPP infrastructure projects as well as explore the perception of stakeholders on project uncertainties for end-to-end sustainability. Differences in opinion among stakeholders on uncertainties often are found to act as a hurdle for effective implementation of PPPs. It is comforting to note that stakeholders have arrived at a general understanding on uncertainties since the inception of PPP projects in India, though there is long way to go. The comprehensive list of the uncertainties brought out in this paper validated by the experts in this field through their experience gained in managing PPP projects in India over the past two decades, when given due consideration while developing Concession Agreements in future will help to institutionalise addressing these unknown unknowns as well as keep the project officers prepared to effectively manage them as and when they unfold.

Keywords:*Perception; Project Management; Public Private Partnerships (PPP); Stakeholders; Uncertainty.*

1. INTRODUCTION

Public Private Partnership (PPP) in development of physical infrastructure has gained popularity in India over the last couple of decades (Wallack & Singh, 2011). PPP contracts are often complex and long-term, extending over several years with high sunk-in investments and are developed in the context of risks and uncertainties making it vulnerable to opportunistic behaviour by the concessionaires. (Ubbels & Verhoed, 2008; Williamson, 1996). Projects are developed with a set of assumptions applied to the macro-economic scenario and are extrapolated to arrive at demand forecasts and cost estimates. Though the demand forecasts have seldom proved to be less than accurate (Flyvbjerg et al. 2003), risks and uncertainties in socio-political, economic and environmental aspects of the project could also result in unexpected outcomes that are detrimental to the project.

Though the phrases 'risks and uncertainties' are invariably used in project management parlance, they have different and wide connotations in PPP contexts. For gaining clarity, risk is a knowable, conceivable or quantifiable threat that unfolds during the course of the project life-cycle, which may endanger the accomplishments of one or more of the project goals (Knight, 1964; Cleden, 2009; Saunders, 2016). Whereas,

*Corresponding Author: E-mail – cpnair@gmail.com

Uncertainties are poorly to not quantifiable threats resulting from lack of information on the project, hampering decision making thereby threatening the achievements of one or more project goals (Keynes, 1937; Cleden, 2009; Mentis, 2015; Grote, 2015). As PPP projects are developed, projects risks are identified and mitigation measures are incorporated in the project agreements so as to address them as and when such situations occur.

For uncertainties, it is either impossible or difficult to foresee all the long-term eventualities, but has a direct correlation on the unavailability or overlooking of certain facts while planning for the project, making it unfavourable for the private investors as well as public and other stakeholders. This gap creates ambiguity and vagueness in designs and development strategies which can result in decisions that lead to undesirable outputs (Dequech, 2000). The inherent uncertainties in these contracts manifest as various turbulences during the post-award stage of the project (Floricel & Miller, 2001). These contractual arrangements are often framed under conditions of uncertainty and are essentially incomplete in nature (Hart, 2003). On the contrary, reducing or coping with uncertainty can also be costly in terms of resources and time (Knight, 1964). Therefore, it is important to plan the evolution of the project into the larger scheme of things and identify the uncertainties as an optimal solution to the existing infrastructure gap.

The uncertainties in the PPP project could be unfavorable for all the stakeholders, especially the private investors for the fact that he has to recoup the sunk investment, its debt service and profit. Therefore, relevant strategies are needed for coping with both negative as well as positive outcomes associated with uncertainty (Dean, 1951). However, for developing strategies it is imperative to understand how the stakeholders perceive the project uncertainties and which of the uncertainties could be the respective stakeholder's priority. This will help in mutually acknowledging the stakeholders leading to a win-win through the project period. This paper looks in to the perceptions of different PPP project stakeholders on uncertainties during the various phases of PPP projects.

2. LITERATURE REVIEW ON UNCERTAINTY AND FLEXIBILITY IN PPP PROJECTS

From the extant literature it is observed that risks and uncertainties are read differently in Economics, Psychology, Philosophy and Organization Theory (Perminova et.al, 2008). As there is a distinctive difference between risk and uncertainties, risk management and uncertainty management are looked upon differently in strategic management literature (Mintzberg, 1994). Projects in different sectors viz. engineering design, engineering systems, manufacturing, smart grids, petroleum etc., also encounter uncertainties due to change in project scenario (De Neufville, 2008). Table 1 presents uncertainties as classified by different researchers.

Table 1: Summary of Classification of Uncertainties from Literature

Author(s)	Types of uncertainties	Description
Milliken (1987)	State uncertainty	State uncertainty is the failure to understand how the components of the environment are changing.
	Effect uncertainty	Effect uncertainty is the inability to understand the impact of events in the environment.
	Response uncertainty	Response uncertainty is the inability to predict the possible consequences of the response are not known.
Lessard and Miller (2001)	Natural	Geology or weather
	Market	Interest rates, risk premium, exchange rates, etc.
	Country/fiscal	Regulatory environment, legal and political stability, contract enforcement, terrorism, etc.
	Industry/competitive	Demand, competition, etc.
	Technical/project	Construction, project management, etc.
Love *et al.* (2001)	Internal uncertainties	Associated with the project, organization, people and finances involved
	External uncertainties	Associated with the government, economy, social and legal uncertainties, technological developments, institutional (organizational) influences, physical conditions and force majeure.
Thunnissen (2003)	Ambiguity uncertainty	Imprecision due to ambiguity in communication
	Epistemic uncertainty	Lack of data or information to support the model

Author(s)	Types of uncertainties	Description
	Sleatory uncertainty	Corresponds to the inherent variation in the variables of the system
	Interaction uncertainty	Arising from unknown outcomes of agents' interaction
Sakhrani et. al. (2013)	Exogenous	Uncertainties outside of the companies' direct control and arise from the market, their operational environment and the cultural and political context.
	Endogenous in system design	Product context and corporate context.
Rice *et al*. (2008)	Technical	Technical uncertainties are related to the completeness of scientific knowledge, the reliability of the process, technical specifications etc.
	Market	Market uncertainties are related to the customers' needs, the types of sales/distribution, and the project team's understanding of the technical, relationship between their product and those of their competitors.
	Organizational	Organizational uncertainties are associated with the dynamics of the organization.
	Resource Innovations	Resource uncertainties refer not only to financial resources but also to all types of skills.
Sicotte and Bougault (2008)	External uncertainty	External uncertainties correspond to the lack of information related to external factors
	Internal uncertainty	Organizational interdependence
	Characteristics of activity	The characteristics of the activity assume two dimensions: variety and analyzability. Variety is caused by research and development activities. Analyzability is a well-structured process and can be used to develop problem solutions.
Koppinen and Rosqvist (2010)	Market- oriented changes	
	Technological changes	
	Changes in network	
	Societal changes	
Sanderson (2012)	Uncertainty Category 1 subjective probability	Uncertainty type 1 is equivalent to known unknowns. Known range of possible future events are available but no data to assign objective probabilities to each.
	Uncertainty Category 2: socialized	Type 2 uncertainties are unknown unknowns. The future is inherently unknowable and may bear little or no relation to the past or the present.
Zheng and Carvalho (2016)	Variability or statistical uncertainty	Variability is caused by various influences yielding a range of values for a particular activity.
	Predictable uncertainty or scenarios	Predictable uncertainties are identifiable and influences understood but it is not possible to know whether they will occur.
	Unpredictable or recognized uncertainty	Unpredictable uncertainties are not identifiable and consequently, there are no a priori mitigation plans.
	Chaos or total ignorance.	Projects with the project plan uncertain and reflect a situation in which the project team does not even know what is unknown.

From the above, it is clear that there is a difference in perception about uncertainties across projects and project stakeholders. For long-term and complex project like PPP it is essential to explore the perception on uncertainties of different stakeholders leading to successful implementation, operation and service delivery of the project.

An extensive review of extant literature with focus on fundamental uncertainties in mega projects/ PPP projects was done initially to come up with a superset of uncertainties that manifest in PPP projects as shown in Table 2.

Table 2: Uncertainties in PPP Projects from Literature

Sl. No.	Uncertainties / Authors	Demirel et.al. (2017)	Zheng and Carvalho (2016)	Mahalingam and seddon, (2015)	Domingues et.al. (2014)	Cardin (2013)	Cruz and Marques (2013)	Perminova (2011)	Athias and Saussier (2007)	Wangand DeNeufville (1984)
1	Delays in land acquisition			x		x			x	
2	External linkages	x					x		x	
3	High finance costs	x			x	x	x	x		x
4	Planning uncertainties	x	x		x			x	x	
5	Poor public decision-making	x	x		x		x	x		
6	Project data and demand assessment	x	x	x	x		x	x		x
7	Project exclusivity		x		x			x		
8	Design uncertainty				x	x	x	x	x	
9	Construction uncertainty		x	x	x		x			
10	Cost uncertainty	x				x	x			x
11	Approvals uncertainty		x			x			x	
12	Additional Site uncertainty			x		x				
13	Completion uncertainty						x			
14	Environmental uncertainty	x	x	x				x	x	x
15	Poor financial market	x					x			
16	Force Majeure	x	x			x	x	x	x	
17	Insolvency of concessionaire							x		
18	Contractual uncertainty				x		x	x	x	
19	Performance uncertainty				x		x	x	x	x
20	Operations uncertainty		x		x		x	x	x	
21	Maintenance uncertainty		x		x		x	x	x	
22	Demand uncertainty		x	x	x	x	x	x	x	x
23	Market uncertainty	x	x	x		x	x			x
24	Revenue uncertainty					x	x		x	
25	Financial uncertainty	x	x	x	x		x		x	x
26	Payment uncertainty								x	
27	Inflation uncertainty		x				x		x	
28	Currency Exchange	x	x				x	x	x	
29	Technical uncertainty		x			x	x	x		x
30	Technology uncertainty	x		x	x	x	x	x		x
31	Insurance uncertainty						x			
32	Political and Regulatory uncertainty	x	x		x	x	x	x	x	x
33	Expropriation and Nationalization uncertainty		x		x		x	x		
34	Operators uncertainty	x				x		x		
35	Terminal value uncertainty		x						x	
36	Sponsor uncertainty	x						x		
37	Social uncertainty	x	x	x				x	x	x

3. METHODOLOGY

3.1. IDENTIFICATION OF UNCERTAINTIES IN VARIOUS PHASES OF PPP PROJECTS

Interactions were carried out with 14 professionals from all stakeholder groups who work or have worked in transport PPP projects in India to take their views and the superset arrived at from the literature was further refined and validated for Indian context. During the interaction a few uncertainties, viz., Uncertainty in change of public needs, Tenor and refinancing uncertainty and Resource uncertainty were proposed and included in the superset. A proposed classification of forty uncertainties evolved as a result of this exercise is presented in Table 3.

Table 3: Classification of Uncertainties

Uncertainty type	Uncertainties	Uncertainty type	Uncertainties
Demand uncertainty	Demand uncertainty	Financial uncertainty	High finance costs
	Project data and demand assessment		Market uncertainty
	Uncertainty in change of public needs		Poor financial market
Public uncertainty	Political and Regulatory uncertainty		Revenue uncertainty
	Poor public decision-making		Financial uncertainty
	Planning uncertainties		Payment uncertainty
	External linkages		Inflation uncertainty
	Project exclusivity		Currency exchange
	Expropriation and Nationalization uncertainty		Insurance uncertainty
	Sponsor uncertainty		Tenor and refinancing uncertainty
	Contractual uncertainty	Private uncertainty	Cost uncertainty
Clearances uncertainty	Approvals uncertainty		Completion uncertainty
	Social uncertainty		Design uncertainty
	Environmental uncertainty		Construction uncertainty
	Delays in land acquisition		Insolvency of concessionaire
	Additional site uncertainty		Operators uncertainty
Force majeure Uncertainty	Force majeure	Technical uncertainty	Technical uncertainty
Operation and maintenance uncertainty	Performance uncertainty		Technology uncertainty
	Operations uncertainty	Handover uncertainty	Handover uncertainty
	Maintenance uncertainty		Terminal value uncertainty

To extract the perceptions of various stakeholders on PPP Uncertainties, the above superset was brought under four different phases of a PPP project, viz., project development, construction, operation and hand over phase. This was again validated and, wherever necessary, modified with the support of 9 PPP experts with adequate experience and exposure to PPP projects to review the comprehensiveness of these uncertainties. A total of 8 uncertainties in project development phase, 16 in construction phase, 23 in operation phase and 7 handover uncertainties, totaling to 54 uncertainties, were assimilated at the end of this exhaustive exercise. These uncertainties that can unfold in various phases of a PPP project are presented in Table 4. Successively a questionnaire survey was conducted among public sector, private investors, consultancy firms, academia and financiers to evaluate the criticality of the identified uncertainties.

Table 4: Uncertainties in Various Phases of PPP Project

Sl. No.	Project development phase uncertainties	Sl. No.	Operation phase uncertainties	Sl. No.	Handover uncertainties
1	Delays in land acquisition	1	Performance uncertainty	1	Handover uncertainty
2	External linkages	2	Operations uncertainty	2	Terminal value uncertainty
3	Project exclusivity	3	Maintenance uncertainty	3	Sponsor uncertainty
4	Project data and demand assessment	4	Demand uncertainty	4	Technical uncertainty
5	Poor public decision-making	5	Environmental uncertainty	5	Technology uncertainty
6	High finance costs	6	Social uncertainty	6	Environmental uncertainty
7	Market uncertainty	7	Market uncertainty	7	Social uncertainty
8	Planning uncertainties	8	Revenue uncertainty		
Sl. No.	**Construction phase uncertainties**	9	Financial uncertainty		
1	Design uncertainty	10	Inflation uncertainty		
2	Construction uncertainty	11	Currency Exchange		
3	Cost uncertainty	12	Technical uncertainty		
4	Approvals uncertainty	13	Technology uncertainty		
5	Additional Site uncertainty	14	Insurance uncertainty		
6	Completion uncertainty	15	Political and Regulatory uncertainty		
7	Environmental uncertainty	16	Expropriation and Nationalization uncertainty		
8	High finance costs	17	Force Majeure		
9	Poor financial market	18	Operators uncertainty		
10	Social uncertainty	19	Sponsor uncertainty		
11	Political and Regulatory uncertainty	20	Contractual uncertainty		
12	Expropriation and Nationalization uncertainty	21	Uncertainty in change of public needs		
13	Force Majeure	22	Resource uncertainty		
14	Sponsor uncertainty	23	Tenor and Refinancing uncertainty		
15	Insolvency of concessionaire				
16	Contractual uncertainty				

3.2. *DATA COLLECTION AND ANALYSIS*

In the questionnaire survey the experts were requested to respond to a five point Likert scale with respect the severity of the impact of different uncertainties in various phases of the project. Online survey software QuestionPro was used to distribute the survey and collect the perceptions of stakeholders with experience in handling PPP road infrastructure projects. A total of 285 stakeholders from five sectors were reached out to understand their perceptions on the various uncertainties PPP projects face and 62 responses were received, of which 55 were found to be complete and valid (response rate 19.3%). These were respondents from public sector (20.09%), private (16.36%), consulting firms (21.82%), academia (18.18%) and financiers (14.55%) with a minimum of five years of experience in PPP projects.

Response data was analysed using IBM statistical package SPSS21 software. Initially descriptive statistics such as mean and standard deviation was used. This was followed by Kendall's concordance test, (Kendall's W), Kruskal-Wallis test and Mann–Whitney U test. Kendall's concordance analysis was done to test the level of consistency of the perceptions of five stakeholder groups on the uncertainties listed out in the four phases of PPP project. The mean score ranking analysis was also conducted to ascertain the relative importance of each uncertainty from the perspective of each group of stakeholders. Finally, to investigate the significant differences on the perceptions of various uncertainties among people from public sector and private consortia, consultants, academicians and financiers the Kruskal –Wallis test was conducted. Further a post-hoc analysis was conducted using the Mann–Whitney U test to understand, where the significant differences in perception lie between the stakeholders from different sectors.

4. RESULTS AND DISCUSSION

As PPP projects are long term, with limited project information, and have different stakeholders than a normal construction project, uncertainties could creep in as new project information's are available. This study has identified all possible uncertainties from project development phase to hand-over and aims to bring out the perception of various stakeholders on these uncertainties. Along with identifying the uncertainties perceived and addressed properly by the stakeholders over a period of time, the exercise will further enable the stakeholders to concentrate on those uncertainties which need to be addressed from now on while developing projects so that projects are undertaken and operated stably leading to sustainability of PPPs.

4.1. TESTS ON AGREEMENT OF RESPONSES

The Kendall's concordance test was done to assess level of agreement/disagreement between stakeholder groups about their perceptions on the severity of impact of uncertainties that may manifest during the various phases of PPP projects. Test was performed at a significance test value of 0.05.

The test was taken with a null hypothesis that "there is no consistency in the perceptions given by the experts". W can range from 0 to 1, where a value close to 1 indicates a strong agreement between the respondents and close to 0 indicates strong disagreement. However, Kendall's W test is suitable only when the number of elements (N) is less than 7 as put forth by Siegel and Castellan (1988). However, if N is greater than 7, chi-square ($\varkappa^2$) test should be the best option. This suggests that the chi-square value should be referred to rather than W (Osei-Kyei & Chan, 2017). The computed chi-square values on the perceptions of uncertainties in all four phases by the five stakeholder groups exceeded the critical value of chi-square (9.49) in all cases. This required that the null hypothesis be rejected for the five groups, suggesting that there is consistency in the ratings by experts within each group. This also reaffirmed the validity of the survey responses for further analysis.

4.2. MEAN SCORE RANKING OF UNCERTAINTIES

The mean score analysis and rankings of various uncertainties in different phases by the stakeholder groups was done. Wherever mean values were the same, the one with lower variance was ranked higher. There were wide variations observed in the mean rankings among various stakeholder groups for certain uncertainties. At the same time their perceptions with regard to the criticality of certain uncertainties matched very well.

Among the eight uncertainties identified in the project development phase the ones that are considered as critical by people from all five sectors are Market uncertainty, Project data and demand assessment and delays in land acquisition. This could be due to the robustness of the markets reflects in the proactive participation of private sector in PPP projects. Project data and demand assessment faces a vital role as base data and demand forecasts have seldom proved to be less than accurate (Flyvbjerg et al., 2003) and reflects adversely on the project. Indian PPP projects used to be delayed due to issues in land acquisition and had a negative connotation on projects' timely completion and commencement of operation.

Among the construction phase uncertainties, completion uncertainty has been perceived as most crucial to the project by all respondents. High finance cost has been ranked second by private, consultants, academicians and financiers and has been ranked fourth by the public. Additional site uncertainty has been positioned third by all, except by the financiers. As the projects get implemented there will be a number of unaccounted but minor issues that may pop-up, for e.g. a pipe-burst, which has potential to stall the construction. These have to be identified and addressed adequately facilitating the completion of the construction. This could also be read with the third uncertainty for additional site to circumvent such challenges. As finance comes at a cost any delay in construction and commencement of operation will strain the debt servicing and hence this will be of concern to investors and financiers.

Demand uncertainty, performance and uncertainty in change of public needs can be considered as crucial in the operation phase of PPP projects and handover uncertainty, terminal value uncertainty and technology uncertainty can be considered critical from among the seven handover uncertainties. PPP projects are developed based on the demand to address a particular gap in the infrastructure. Demand forecasts have proved to be less than accurate (Flyvbjerg et. al., 2003), and this could affect the project especially the project cash flows and debt servicing. Project performance delivering the desired service including quality of construction and of service delivery is a challenge during the operation stage. PPP projects are long-term and have sunk-in costs (Ubbels & Verhoed, 2008) designed to address a particular gap in infrastructure. With time, along with progressive development initiatives and technological advancements, there is a possibility of change in the public needs, which could affect the project. As the project has to be handed over at the end of the agreement period, the process, procedures and compliances should be in place for the same. However, as the project periods are particularly long, no such procedures and compliances exist. Procedure for identification of the terminal value and addressing the technological obsolescence are also unpredictable during the project development/operation stage.

4.3. SIGNIFICANT DIFFERENCES IN THE PERCEPTIONS OF UNCERTAINTIES AMONG STAKEHOLDERS

From the 54 uncertainties grouped in four phases, the stakeholders have consensus on 28 uncertainties. In other words, since the inception of PPP projects in India, in mid-1990s, the stakeholders have arrived at a general understanding on these uncertainties. Difference still exists on many other uncertainties and the stakeholders have to address those to make PPP projects sustainable. Opinions differ in part not only because each group of interviewees have different objectives, but also because each has a different vision of what PPPs should achieve. During the survey and while undertaking the analysis, wherever perceptions differed among stakeholders are discussed in the sections 4.3.1 to 4.3.4.

4.3.1. DIFFERENCES IN PERCEPTION OF UNCERTAINTIES AMONG STAKEHOLDERS IN PROJECT DEVELOPMENT PHASE

The Kruskal – Wallis test was performed for the project development phase, helped examine whether the differences in perceptions of stakeholders are statistically significant or not. The test results indicate that among the eight uncertainties that can manifest in the project development phase, there exist significant differences in the perceptions of the stakeholder groups with regard to the five uncertainties as their þ-values are less than 0.05.

Among the 16 construction phase uncertainties, five uncertainties present significant difference in perceptions of stakeholders as regard to their criticality. These are cost uncertainty, completion uncertainty, poor financial market, political and regulatory uncertainty and sponsor uncertainty. Twelve among twenty three uncertainties in the operation phase and four among seven handover uncertainties have significant differences in the perceptions of the stakeholders. Kruskal – Wallis test results only established which among the various uncertainties are statistically different as per the perceptions of the stakeholders. This test did not reflect where the significant differences lie between the stakeholders.

Mann- Whitney U test was conducted subsequently to understand, between which set of stakeholders do perceptions differ. The test was done at recalculated alpha value of 0.01(0.05/5). The test was done on the five uncertainties in project development phase which showed significant differences in perceptions of stakeholders' viz., project data and demand assessment, poor public decision making, high finance costs, market uncertainty and planning uncertainties. The test results of ten pair wise comparisons done between five stakeholder groups on these uncertainties showed that there are differences in opinions between certain stakeholder groups.

With respect to project data and demand assessment uncertainty there existed notable difference in perception of public against other stakeholders. As far this uncertainty is concerned, the rest of the stakeholders run a high uncertainty on the base data and the demand projections based on which the entire project stands. Any change in the data and demand assessment will directly reflect in the operational sustainability of the project.

Difference in perception exists between public and private as well as public and consultants in poor public decision making uncertainty as the latter expect some non-reliability on the public's decisions on the project.

Opinion differ on financing costs between private and academicians, as private may have critical and first hand understanding of the intricacies of financing and cost involved in mobilizing and servicing the finance.

Private, Consultants and financiers have higher impacts due to market uncertainty which will ultimately generate lesser interests in bidding and/or difficulty in financial closure of the project. This was reflected in the difference in mean ranking between the three stakeholders and public. Akin, the consultants and financiers have a higher and first hand understanding on market uncertainty than academicians as they work in the cutting edge of PPP projects.

Private and financiers are meticulous in planning the development and implementation of PPP projects addressing all possible avenues of uncertainties making them more efficient in the field, where as academicians might be process oriented and extends more emphasis on in-house planning exercises than other stakeholders. This might be the reason for difference in perception between Academicians and financiers on planning uncertainties.

4.3.2. DIFFERENCES IN PERCEPTION OF UNCERTAINTIES AMONG STAKEHOLDERS IN CONSTRUCTION PHASE

Mann Whitney test on uncertainties in construction phase was done where Kruskal Wallis test results indicated significant differences in perceptions of stakeholders.

In the construction stage, significant variations in perception were observed among stakeholders in cost uncertainty, completion uncertainty and poor financial market. In cost uncertainty there was variation between private and consultants as well as consultants and financiers. The variation between private and consultants could be because the financiers have hands-on and on-the-field knowledge on the cost implications of the projects as well as the possible over-runs that can creep in during the construction phase than consultants who generally works on thumb rules. In consultant verses financiers, financiers with a higher mean rank have a better understanding on cost uncertainties than consultants. Learnings accrued from previous experiences in change in cost during the construction phase can be attributed to this understanding by the financiers.

Between public and consultants, consultants are more hands-on with the project and thereby are more aware of project and construction related challenges. They interact more with project stakeholders and also have analyzed construction operations in associated locations and this is depicted in the higher mean rank of consultants in completion uncertainty.

With respect to poor financial market uncertainty, mean ranking of Public is low and there exists significant difference in perception of public with all other stakeholders. In all the cases, p-value is less than the significant test value of 0.01. The difference between public and private could be such that private investor invariably works in line with the financial market and funds are available at attractive rates only when financial markets are good. On the contrary, funds will be costly in poor markets scenario limiting the private sector to take up PPP projects, whereas public may be more concerned on the timely completion of the project.

Reason for difference in perception between public and consultant can be attributed to consultant's interaction with the private sector as well as financiers to elicit and identify their interests on projects which makes them more aware of the projects affinity toward the financial market trends. With robust financial trends, the consultants will be confident on the number of players for the bidding process. The variation between public and academicians could be possibly due to academician's critical emphasis on better financial markets against the evidences on poor interests in bidding for PPP projects during poor financial markets. The public sector, on the other hand, will be interested only on timely completion of the project and may not be interested on the source of funds. Significant difference on ranking of 'poor financial market uncertainty' between public and financiers can be attributed to less availability of cheap finance during poor markets for deployment for construction of the project and hence financiers see it as a major uncertainty.

4.3.3. DIFFERENCE IN PERCEPTION OF UNCERTAINTIES AMONG STAKEHOLDERS IN OPERATION PHASE

Of the twelve uncertainties identified during the operation phase, seven of them viz., demand uncertainty, market uncertainty, revenue uncertainty, financial uncertainty, technical uncertainty, technology uncertainty, resource uncertainty and, tenor and refinancing uncertainty yielded significant differences during pair wise comparison during Mann Whitney test.

Between public and academicians, academicians may have extended more weight to demand uncertainty on the possible academic evidence that demand has a positive correlation in the operating phase leading to operating cash flows and debt servicing keeping the project on track. Private must have extended more weightage to market uncertainty because they are more involved in the sector and hands-on with the market trends than the academicians. Between consultants and academicians, consultants must have perceived market uncertainty as critical since they are more involved with the sector developments and connected trends while developing projects than the academicians.

In public verses consultants, consultants consider higher revenue uncertainty as crucial because revenue (as well as cash flows) is required to keep the project performing and hence they would have looked into various options of revenue other than fare box collections. With adequate avenues of revenue, the consultants make sure that the project will be a profitable venture. Mann Whitney pair wise comparison between private and academicians on revenue uncertainty yield a higher mean ranking for the private. This could be because the private sector may be aware of the fact that the fare box collection will not be sufficient to keep the project performing and to service the debt, and hence need alternate sources of income. Therefore, private will rate revenue uncertainty at a higher scale, whereas academicians will be looking at service delivery of the project. Mean ranking for revenue uncertainty of consultants is higher than the academicians. This could be because they will be in pursuit for making the project financially viable and hence will be looking at additional revenue streams along with fare box collections.

For financial uncertainty a comparison of public and private indicated that the private sector has prioritized financial uncertainty since it has a direct correlation on operation of the project and especially in the alternate and additional revenue streams helping them in debt servicing and proper Operation and Maintenance of the project. With respect to technology uncertainty when compared to public mean rank obtained for private, consultants, academicians and financiers are higher. This might be due to the reason that private, consultants, academicians and financiers might have associated more weightage to technology uncertainty as technology can be obsolete over a period of time and can affect the project adversely especially the operational efficiency. In other words, public may look at satisfactory operation of the project while the rest of the stakeholders placed emphasis on the operational efficiency of the project.

Resource uncertainty had a lower mean rank by the public, compared to that of the private sector. This implies that the private sector rated the resource uncertainty far higher than the public. The private must have considered that resources are vital for efficient and effective operation of the project which can result in superior service delivery along with operational profits and debt servicing.

As far as tenor and refinancing uncertainty is considered significant difference in ranking was observed between public and consultants. A possible reason for this may be because, consultants keeps the options open for tenor and refinancing if the project runs into some trouble during its operations, whereas the public expects the project to be stand-alone from day one of operations.

4.3.4. DIFFERENCE IN PERCEPTION OF UNCERTAINTIES AMONG STAKEHOLDERS IN HANDOVER PHASE

Kruskal Wallis test results brought out that significant difference existed in four out of seven uncertainties. p-values obtained was less than 0.05 for terminal value uncertainty, technology uncertainty, environmental uncertainty and social uncertainty. To find out where these differences lay Mann Whitney test was carried out.

Between public and private, public and consultants, public and financiers, people from the private sector, consultants and financiers consider terminal value uncertainty to be significant. This might be because there could be situations of default, expropriation or a force majeure, so as to cover the losses and other commitments the project has committed. There is a significant difference in mean ranking between academicians and financiers with financiers extending a high priority to terminal value uncertainty. Financiers with their practical knowledge and understanding in managing similar projects would have prioritised terminal value at a higher ranking than academicians, who would look for the framework and process for assessing terminal value.

For technology uncertainty, pair wise comparison results of public and consultants, public and academicians and public and financiers indicate that consultants, academicians and financiers have prioritised technology uncertainty, may be because technology can become obsolete over a period of time and can affect the project adversely. While public may is more concerned with handover of a project which is operational the rest of the stakeholders may emphasise upon the operational efficiency.

5. SUMMARY

The present study has identified 40 uncertainties associated with PPP projects in an endeavour to address them while developing future initiatives. These uncertainties were then grouped under the four phases of the PPP project and with some of them found to manifest in more than one phase a total of 54 uncertainties are listed and analysed in this study. The perceptions of stakeholders on these uncertainties associated with Indian PPPs were received through a questionnaire survey. The data was used to identify uncertainties which the stakeholders consider as critical to the project life cycle. Of the 54 such uncertainties across the phases, for which perceptions were analysed, it was found that stakeholders were in thorough consensus for 53 percent of the uncertainties. This implies that the stakeholders must have arrived at a general understanding on these uncertainties since the inception of PPP projects in India. For the remaining 47% of the uncertainties, analysis was further done to determine those stakeholder groups' who differed in their perception on the criticality of uncertainties. This was carried out in an attempt to reason out the causes for difference in perceptions between stakeholders. Opinions differ in part not only because each group of interviewees have different objectives, but also because each has a different vision of what PPPs should achieve. Nevertheless, narrowing down these differences in opinion on uncertainties will significantly help effective implementation of the uncertainty management strategies leading to sustainable PPPs. In addition, the comprehensive list of the uncertainties brought out in this paper validated by the experts in this field through their experience gained in managing PPP projects in India over the past two decades, when given due consideration while developing Concession Agreements in future will help to institutionalise addressing these unknown unknowns as well as keep the project officers prepared to meet unforeseen situations.

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SUITABLE GOVERNMENT INITIATIVE STRATEGY FOR BIM IMPLEMENTATION IN SRI LANKA

M.S. Siriwardhana[1], H.S. Jayasena[2], M.K.C.S. Wijewickrama[2*] and L.M.B.N. Kolugala[2]

[1]Al Arabia Electromechanical LLC, United Arab Emirates

[2]Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Construction industry has encountered various innovative technologies over the past decades. Growth of these innovative technologies has paved the way to improve the performance and productivity in the industry. Building Information Modeling (BIM) is a revolutionary paradigm which supports Architecture, Engineering, Construction and Operations (AECO) industry to improve its efficiency and effectiveness to deliver economical and quality products. AECO industries in many countries are gaining immense advantages by adapting BIM. There are six roles which foreign governments have played in BIM implementation strategy. Government authorities in other countries have adopted these roles in their BIM implementation strategy, while encouraging private sector to acclimate. Moreover, there are various BIM implementation strategies developed by different governments all around the world. Majority of successful BIM implementations rest with the improvement of the basic BIM competencies. In Sri Lankan perspective, fewer people aware on BIM and government has completely disregarded this novel technology which can contribute massive benefits to the local construction industry. There are numerous challenges which barricade the adaptation of BIM in Sri Lanka. This research aims to identify a suitable government initiative strategy that can be adapted to implement BIM in Sri Lanka. Espousing this suitable strategy will eliminate barriers against BIM and improve basic BIM competencies which are needed to improve BIM implementation in Sri Lanka.

Keywords: *Building Information Modelling (BIM); Construction Industry; Sri Lanka.*

1. INTRODUCTION

Bestowing to Rameezdeen et al., (2006), the construction industry development is a paramount source for national economic enlargement. Sri Lanka (SL) is experiencing a massive growth in its construction industry after jeopardized by few natural disasters and long lasted civil war (Davies, 2014). Supportively, Davies (2014) explicated that Sri Lankan construction industry has significantly supported the growth of national economy by accelerating 6.6% to 8.7% of Gross Domestic Product (GDP) from 2009 to 2013. As per Wasantha and Jayasinghe (2013), construction sector GDP mounted at US$ 1.9 billion in 2012 by achieving a growth rate of 21.6% compared to the GDP growth 6.4% and industry sector growth of 10.3%. Moreover, Department of Census and Statics (2011) expounded that public sector contribution to the estimated value of work done by all type of construction activities was 74% and private sector contribution was 26%. Further, it mentioned that the highest contribution to estimated value of work has been made by building construction sector and it was accounted for 48% of total value of work done. Henceforth, the construction industry development can be considered as one of the main driven factors of Sri Lankan economy.

Royal Institution of Chartered Surveyors (RICS, 2014) stated that the construction industry is highly vulnerable to late completions, budget overruns and poor quality output. Building Information Modelling (BIM) is one of main technological advances that offers the potential upsurge of efficiency and effectiveness to construction projects (Azhar, 2011). According to Aibinu (2015), BIM is an intelligent model-based method of creating and

*Corresponding Author: E-mail – mkcsw.mora@gmail.com

handling construction project information from inception to operations stages by using 3D modelling software to reduce time and material. Further to him, through BIM, project

can be pre-seen before construction and helps to improve the performance of the project. Furthermore, it increases the collaboration between project team members while reducing cost, increasing profitability and improving time management. In order to adapt this transformation in the construction industry, both private and public sector stakeholders in many countries have started different BIM implementation strategies (Wong et al., 2009).

Smith (2014) exposed that the national leadership is an essential prerequisite for successful BIM implementation. Further to him, government should be the pioneer in BIM implementation while the support and collaboration of major private sector clients and professional associations are also vital. Jayasena and Weddikkara (2012) specified that BIM is experiencing its infant stage in Sri Lankan construction industry. Further to them, even if this advanced paradigm can bring a new era for local construction industry, limited people conscious on its applications and supreme benefits. Henceforth, Jayasena and Weddikkara (2012) expounded that BIM is a technology that Sri Lankan construction industry should embrace and most of the challenges are unlikely to be weighty if there is a commitment and proper initiative strategy. Thus, this research aims to identify a suitable government initiative strategy to adopt for implement BIM in SL, considering strategies which were developed by BIM using countries to implement BIM in SL.

2. RESEARCH METHODOLOGY

With the requirement of identifying a suitable government initiative strategy to adapt for implement BIM in Sri Lanka, a qualitative approach was utilized. In order to proceed with the qualitative approach, initially, a desk study was conducted through the analysis of online government reports and presentations, online research publications online forums, websites, online newspapers, online magazines and BIM guidelines. After the collection the data, a content analysis was conducted using a computer based content analysis software namely NVivo (version 10). Then, eighteen semi structured interviews were conducted among various field players such as contractors, consultant, architects, government authorities, and educational institute and information technology companies. Since this research is purely focused on a strategic solution to implement BIM in Sri Lanka, most of interviews were carried out with industrial experts in the managerial hierarchy who are engaged in decision making. Table 1 exposes the respondent profile of the conducted interviews.

Table 1: Respondent Profile

Organization	Respondent	Field player group	Designation	Experience
01	R1	Construction	General Manager	20 years
02	R2	Construction	Assistant General Manager	15 years
03	R3	Construction	Assistant General Manager	16 years
04	R4	Consultant (QS)	Contracts Manager	19 years
05	R5	Consultant (QS)	Chief Quantity Surveyor	17 years
06	R6	Consultant (QS)	Director	22 years
07	R7	Architect	Design Manager	15 years
08	R8	Architect	BIM Consultant	19 years
09	R9	Architect	Chief Coordinator	14 years
10	R10	Government authority	Assistant Manager	12 years
11	R11	Government authority	Chartered Engineer	16 years
12	R12	Government authority	Manager	10 years
13	R13	Education institute	Director	9 years
14	R14	Education institute	Student	-
15	R15	Education institute	Student	-
16	R16	Education institute	Student	-
17	R17	Education institute	Student	-
18	R18	Information technology company	General Manager	12 years

3. BUILDING INFORMATION MODELLING (BIM)

BIM is a modern technology which virtually constructs a building in detail before constructing it physically (Smith, 2007). Building SMART alliance (2015) define a building information model as a "digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward". Chelson (2010) stated that BIM can be used to generate solutions for problems by simulating a graphical model which is built based on the design intention and gives a clear picture of design issues and constructability problems. Therefore, construction productivity upgrade due to adaptation of BIM because those problems can be resolved in the early stage of the project.

4. INTRODUCTION ON BIM FRAMEWORK

BIM framework allows AECO industry stakeholders to understand the required primary knowledge layout for BIM and capabilities of BIM which will lead to understand the requirements for BIM implementation. According to Succar (2009), BIM framework is multi-dimensional tri axial model which is comprised of BIM fields, stages and lenses.

4.1. BIM FIELDS AND BIM STEPS

BIM field is a combination of three interlocking but distinctive fields to impelement BIM in a country, there should be an overlap of aforesaid three BIM fields.

Table 2: BIM Fields - Players, Deliverables and Interactions

BIM field	Extended Field Definition	Players	Deliverables
Technology Field	This field include software hardware and networking systems to support the construction project life cycle.	Software, hardware and networking equipment corporation and their sales channel.	Office/site equipment, software and hardware
Process Field	This is the interaction between design, construction and operational requirements to create and maintain structures.	Owners, operators, architects, engineers estimators, surveyors developers, contractors, sub-contractors suppliers, fabricators, facility managers	Deliver construction product and services which comprise drawings, reports, virtual model and physical section of a construction product.
Policy Field	Policy field is the interaction of producing research, abilities, standards and guides to reduce conflicts between AECO stakeholders.	Governments, researchers, educational Institutions, insurance companies and regulatory bodies	Regulations, guidelines, standards, best practices, bench marks, contractual agreements, educational programs.

Source: (Succar, 2009)

From pre BIM to each BIM stage has its own requirements and deliverables, which will generate various BIM steps. These steps are incremental steps and organized into "sets" based on location of the step in the implementation process. It is essential to gain knowledge regarding these steps, because they will support to improve the capability and the maturity level of BIM in an organized way (Succar, 2010).

4.2. RELATIONSHIP BETWEEN BIM FIELDS AND BIM STEPS

Succar (2009) identified that there is a relationship between BIM fields and BIM steps which will improve the capability and maturity level and lead to next BIM stage. This relationship is illustrated in Table 3.

BIM steps are requirements which should be fulfilled to achieve maturity level for specific BIM stages. BIM steps will identify requirements which is necessary to fulfill each BIM stage requirements and support BIM implementation (Succar, 2009).

Table 3: Relationship between BIM Fields, BIM Steps and BIM Stages

Field/ Competency set	BIM Steps/BIM areas	Example for improving BIM stages.
Technology	Software, Hardware and Networks	Availability of software, hardware and network as BIM tools, will support to move pre BIM stage to object based modelling stage.
Process	Leadership, Infrastructure, Human Resources and Products/Services	Collaboration process and information sharing ability will support to migrate from object based modelling stage to model based collaboration stage.
Policy	Contracts, Regulations and Research/Education	Integrated and risk-sharing contract agreements will support to migrate from model based collaboration stage to integrated practices.

Source: (adapted from Succar, 2009)

4.3. BIM USAGE IN ALL-AROUND THE WORLD

According to Jung and Lee (2015), United States of America (USA), Canada, Netherlands, France, Italy, United Kingdom (UK), Russia, Republic of Korea, India, China (Hong Kong included), Philippines, Taiwan, Singapore, Thailand, Saudi Arabia, Egypt, Lebanon, Jordan, Iran, United Arab Emirates (UAE), South Africa, Qatar, Argentina, Mexico, Brazil, and Chile are some of the countries that immensely using BIM globally. Amongst, governments of some of the countries have become the pioneers and initiators in implementing and developing BIM within their geographical boundaries.

Public sector has a vital role in steering AECO industry for BIM adoption. Accordingly, six main roles of the public sector can be identified based on the review of BIM implementation in different countries for BIM adoption (Cheng & Lu, 2015). Table 4 shows the summary of these six roles of public sector played by countries like USA, UK, Denmark (DEN), Finland (FIN), Norway (NOR), Hong Kong(HK), South Korea (SK) and Singapore (SIN) for successful BIM implementation.

Table 4: Six Roles of Public Sector.

Public sector role	Activities	Adopted Countries
Initiators and drivers	Goals and promises, BIM committees, BIM activities	USA, UK, NOR, DEN, FIN, HK, SK, SIN
Regulators	BIM guidelines, Standardize BIM	USA, UK, NOR, DEN, FIN, HK, SK
Educators	Training programs, Training plans, College BIM education	USA, UK, HK, SIN
Funding agencies	Financial support for BIM implementation.	USA, SK, SIN
Demonstrators	BIM pilot projects, Internal BIM plans, Test BIM technologies	USA, NOR, DEN, HK, SIN
Researchers	R&D projects, Collaborate with research institutions	USA, NOR, DEN, HK, SK, SIN

Source: (adopted from Cheng & Lu, 2015)

According to Table 4, all the governments have played the roles of initiator and driver, regulator in each and every BIM implementation strategy. Therefore, these two roles can be considered as the main and compulsory roles within a BIM implementation strategy. Other four roles have been used occasionally, while considering the industry characteristics within each country. When the industry characteristics are fulfilling the requirements which should be fulfilled by the particular role within the strategy, then that particular role is not considered to develop the BIM implementation strategy for that particular country. Based on the analysis, due to following industry characteristics some countries have not considered some roles when developing their BIM implementation strategy. After considering all the literature findings, Table 5 illustrates the industry characteristics which should consider when deciding roles with in the BIM implementation strategy.

Table 5: Industry Characteristics that should be Considered when Deciding Roles within the BIM Implementation Strategy

Role	Industry characteristics
Demonstrator	Support of BuildingSMART organization for test and demonstrate BIM.
Funding agency	Government funding (UK) Support from leading companies in the industry (NOR) Support from the industry. (DEN) Funding by private companies. (FIN) Fund availability. (HK)
Educator	Availability of BIM education.
Researcher	Support of BuildingSMART organization for researchers about BIM.

Source: (adopted from Cheng & Lu, 2015)

Furthermore, in some situations, aforementioned industry characteristics have become supporting factors for the BIM implementation strategy. To be a successful BIM implementation, there should be a support from BIM field players and should have an active construction industry. Based on the analysis, each and every country has different industry characteristics which show an active construction industry and support from BIM field players. All those industry characteristics which support BIM implementation strategy are mentioned below;

- Contribution to GDP from construction industry
- Growth of the construction industry
- Procurement methods used in the construction industry.
- Support from leading companies in the industry
- Client requirement for BIM
- Partnering with industry
- Availability of technology
- Support from technology companies

5. INDUSTRY CHARACTERISTICS WHICH SUPPORT BIM IMPLEMENTATION STRATEGY

5.1. CONTRIBUTION TO GDP FROM CONSTRUCTION INDUSTRY

As mentioned in a Sri Lanka GDP from Construction (2016), *"GDP from Construction in Sri Lanka increased to 157,734 LKR Million in the third quarter of 2016 from 142,133 LKR Million in the second quarter of 2016. GDP From Construction in Sri Lanka averaged 128,312.48 LKR Million from 2010 until 2016, reaching an all-time high of 170,122 LKR Million in the first quarter of 2013 and a record low of 77,176 LKR Million in the second quarter of 2010."* According to this statement, there is a significant contribution to GDP from construction industry. Hence, above statement reflects that there is an active construction industry in Sri Lanka.

5.2. GROWTH OF THE CONSTRUCTION INDUSTRY

As revealed in a newspaper in 2014, *"the Sri Lankan construction industry last year continued to grow at 20.2 per cent on the back of declining interest rates and low inflation".* Accordingly, there is a growth in local construction industry and this statement confirms the reflection of previous statement.

5.3. PROCUREMENT METHODS USED IN THE CONSTRUCTION INDUSTRY

According to the respondents, traditional method, design and build, Build-Own-Operate-Transfer (BOOT), Build-Own-Transfer (BOT) and Public Private Partnership (PPP) are the procurement methods used in Sri Lanka. However, majority of respondents argued that procurement methods such as design and build are BIM favourable methods. Therefore, there are procurement methods which can support BIM implementation strategy in Sri Lanka.

5.4. *Support from Leading Companies in the Industry*

All the respondents strongly confirmed to support the government initiative BIM implementation strategy. Some respondents have already implemented BIM in their organizations. Respondent R8 who is a BIM consultant expressed, *"Yes, we already implemented BIM in our firm since June 2016. We have mandated BIM within our organization, we design projects through BIM and deliver 2D drawings or 3D BIM model to other disciplines as per their request".* Thus, it proves that some organizations have already implemented BIM within their organizations and they are willing to support local BIM implementation strategy.

5.5. *Client Requirement for BIM*

Five of nine respondents expressed that clients do not require BIM, whereas two respondents stated that clients require BIM in their projects. Further, respondent R6 said, *"BIM is essential for clients to deliver a smooth project by achieving time, cost, and quality targets".* Respondent R7 expressed that, *"95% of clients do not require BIM. They only require 2D drawings. However, there is a trend to use BIM for apartment projects".* Accordingly, it is evidently proved that there is a trend to use BIM in local projects and some clients conscious on the essentiality of BIM for the local context.

5.6. *Partnering with Industry*

All nine respondents are willing to be partners with government to implement BIM in Sri Lanka. Respondent R2 strongly stated that, "*Yes of course, if they come, we will definitely give our support."* This statement proves that industry players are ready for a journey which should be initiated by the government. When consider about the government authorities, all three respondents were eager to be partners with the industry, but they have some limitations as well. As per respondents R10 and R12, they are willing to give their utmost assistance for BIM implementing strategy by be partners with industry, but they have to be knowledgeable on the purpose and applications in advance. Considering all these statements, both government authorities and industry like to be partners with each other for a journey which government should be the pioneer.

5.7. *Availability of Technology*

Respondent R18 discovered that, there are some software related to BIM such as Autodesk products in local context. Further, R10 explicated that *"Capacity of Information Technology Infrastructure (ITI) in Sri Lanka comply with the minimum requirement of ITI in BIM."* Accordingly, ITI in SL is adequate to satisfy the minimum requirement of BIM.

5.8. *Support from Technology Companies*

*Respondent R18 expressed that, "*Yes, we can provide essential software for clients. Most clients ask for Autodesk products but we able to provide other products too*". Thus, technology companies are willing to provide software related to BIM as per requirement of the client and ready to support BIM implementation in Sri Lanka.*

6. Industry Characteristics to be Considered when Deciding Roles within the BIM Implementation Strategy

6.1. *Educators*

Bestowing to the literature, education is significant in the preparation of BIM implementation strategy, with reference to all the countries. The research findings revealed that in Sri Lanka, a proper BIM education seems to be absent irrespective of the education on the BIM related software in the government and private education sector. The private institution provides facilities for the BIM software education whereas in government universities provides BIM related education sessions but no complete BIM education. Additionally, at present some of the construction firms have gained knowledge about BIM related software from private BIM software education centres.

Thus, the respondents suggested that the government has to take the initiative for the BIM education which is not covered from private software education centres. Therefore, government has to perform the role of educator within BIM implementation Strategy in Sri Lanka.

6.2. FUNDING AGENCIES

As per literature, some of the countries are not engaged in the funding for the BIM implementation even there is adequate monetary facilities. However, according to respondents, following characteristics are to be considered in Sri Lankan context to make the decision to move along with the following strategy.

Table 6: Current Status of Funding Agencies in Sri Lanka for BIM Implementation

Factor	Description
Government Funding	Funds are available within the government construction organization although there not yet implemented.
Funding by private companies	Within current Sri Lankan context private companies are interested, invested and receiving the benefits through the use of BIM related software and training.
Support from Leading Companies in the Industry	Leading companies in the industry are interested to support for BIM implementation strategy in Sri Lanka.

6.3. DEMONSTRATORS

6.3.1. SUPPORT FROM AN ORGANIZATION TO TEST AND DEMONSTRATE NEW TECHNOLOGIES

According to literature, the role of demonstrator with in their BIM implementation strategy is not visible with many countries. Similarly, as per respondents, there is no organization to test and demonstrate new technologies in Sri Lanka too. Thus, government has to perform this role within the BIM implementation strategy.

6.4. RESEARCHERS

6.4.1. SUPPORT FROM AN ORGANIZATION FOR RESEARCHES

More or less countries had an organization to carry out research concerning BIM and since of this support they have not considered this role within the strategy. Consequently, when developing the strategy, it is very vital to consider whether there is an organization to carry out researches regarding BIM in Sri Lanka. However, private organization are not receiving and support from any organization to support for researches regarding BIM. Concerning the government organizations, researches were not conducted within them yet universities conduct researches related to BIM. Subsequently there is no particular organization to carryout researches about BIM government have to perform the role of researcher within BIM implementation strategy in Sri Lanka.

7. CONCLUSIONS AND RECOMMENDATIONS

The roles of initiator and driver, regulator are obligatory roles which should be performed with in BIM implementation strategy in Sri Lanka. The role of educator should be performed to fulfil the gap between existing BIM education level and the required BIM education for a successful BIM implementation. The role of funding agency is not much extensive, since funds are available in government organization and private companies also are enthusiastic to invest for BIM. Defiantly, the role of demonstrator should be performed with in the BIM implementation strategy. Currently, there is no government organization to test or demonstrate new technologies such as BIM. The role of researcher could require a less effort because even though there is no specific organization to carry out researches in BIM, universities have started conducting research in BIM. However, the scale of such research does not fully satisfy the requirements of the industry. Thus, finally, considering all findings of the research the roles of initiator and driver, regulator, demonstrator should perform with full effort and the roles of educator and researcher should be included within the strategy but the role of funding agency cannot be considered within developing BIM implementation strategy for implement BIM in Sri Lanka.

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TECHNO-ECONOMIC FEASIBILITY STUDY OF USING SOLAR ENERGY FOR OPERATING SEWAGE TREATMENT PLANTS

R.R. Omprakash[1], Sivakumar Palaniappan[1*] and Pandian Ganesh Kumar[2]

[1]Building Technology & Construction Management, Department of Civil Engineering, Indian Institute of Technology Madras, India

[2]Water & Effluent Treatment IC, Larsen & Toubro Construction, India

ABSTRACT

Sewage treatment plants are the major consumers of energy throughout the world and most of the studies consider completely self-sufficient treatment plants or off-grid solar PV. This study presents the findings of the techno-economic feasibility study of using on-grid fixed tilt polycrystalline solar photovoltaic (PV) modules to generate power for operating small capacity sewage treatment plants (STP) ranging from 1 to 10 MLD. Recent ongoing 4 STP projects in Rajasthan, India is considered for the study. With fixed-tilt solar PV system, the maximum PV array capacity need to be installed is found to be 99kWp, 131kWp, 172kWp and 403kWp for 1.5, 2, 3, 8 MLD STP's respectively. Life Cycle Cost Analysis of a base case scenario with 30 years of service life and 10% discount rate indicates that the Net Present Value (NPV) of the system comes around 3.7 Million INR, 5 Million INR, 6.5 Million INR and 15.3 Million INR for 1.5, 2, 3, 8 MLD respectively. The Internal rate of return (IRR) is found to be 18.5%, the normal payback period to be 5.4 years and Discounted Payback period to be 8 years for all 4 STP's. Life Cycle Assessment results of the Solar PV modules indicates that the energy payback period is coming around only 1.6 years with carbon payback period of 142 days in comparison with conventional coal-based power plants. It is found that application of Solar PV in operating STP's is highly favourable technically, economically as well as environmentally in a tropical Country like India.

Keywords:*Life Cycle Cost; Power Generation; Sewage Treatment Plant; Solar Photovoltaic.*

1. INTRODUCTION

Sewage treatment plants (STP's) are widely used to remove the harmful emissions before mixing with receiving water bodies (Enger et al., 2000). But most STP's are widely designed to cater to the desired treated effluent characteristics without much consideration given to energy (Rojas & Zhelev, 2012). Municipalities more often rank STP's as the major individual energy consumers (Wett et al., 2007). It was recorded that in a conventional STP, about 25-40% of operating costs is directly linked with energy consumption (Panepinto et al., 2016). In addition to high energy consumption, the greenhouse gas emissions in STP is of great concern (Ashrafi et al., 2014). Therefore, there is an immediate need either to bring down the energy consumption from STP's or otherwise reduce the energy dependency on conventional sources of energy.

2. LITERATURE REVIEW

Energy efficient STP's is a common topic of interest among scientific community (Awe et al., 2016; Matos et al., 2014; Estrada et al., 2015). Many researches have been done in the past to record the energy consumption of STP's and different options for producing energy from the renewable sources have been tried out. In the beginning, recovery of biogas from sludge to partly meet out the energy demand in wastewater infrastructure was recommended (Tran et al., 2015). Going further, studies described such methods in detail for recovering biogas from the sludge (Van der Hoek et al., 2016). A study recorded the energy consumption during operation

*Corresponding Author: E-mail – sp@iitm.ac.in

for different methods of treating waste water which includes oxidation ditch process, Activated Sludge Process (ASP), and ASP with lime stabilization (Rodriguez-Garcia et al., 2011). By latest, possibility of energy self-sufficient wastewater treatment plants along with their challenges was explored. One of the main energy resource described is the biogas from the digestor (Gu et al., 2017). However, there is a huge gap for the self-sustaining STP's in developing as well as developed countries because of the technology used, costs and environmental protection issues. Presently, Sequential Batch reactor (SBR) is one of the key technology used for sewage treatment widely used along the globe and this is one of the most energy consuming technology in comparison with other conventional treatment technologies like conventional activated sludge systems (CAS). The energy consumption for different technology treatment plants was investigated in China and found that the average energy consumption of STP's working with SBR technology is 0.336 kWh/m3 and that of CAS as 0.269 kWh/m3 (Yang et al., 2010).

SBR technology is a variant of conventional ASP preferred now mostly throughout the world and especially in India because of seemingly high advantages. SBR requires almost 40% area compared to conventional ASP because of its compactness of treatment occurring in a single tank. SBR is mostly completely automated while conventional ASP is not fully automatic. These are some of the reasons for choosing STP's operating with SBR technology as the scope of study because of its applicability in the entire world and especially in India.

A STP operating in India with SBR technology consumes total Energy consumption of 28.21 kWh/pe-per year (i.e. 28.21 kWh per capita per year) over the complete life cycle of the Plant of which 99.7% is operational phase energy (Kalbar et al., 2012). Construction phase contributes only 1% for the impacts when compared to the Overall Life Cycle impact of the STP and can be neglected (Kalbar et al., 2012). The highest environmental impact during Operation and Maintenance (O&M) is mainly because of the energy consumption required for aeration in SBR process because of the continual supply of air (Machado et al., 2007; Gaterell & Lester, 2000).

Generating biogas from STP's sludge to meet out some power was tried in many places throughout India but was not successful as planned. According to Ministry of Environment & Forests Parivesh Bhawan (2007), the report of complete Evaluation of O&M of STP's in India was carried out and it was inferred that there was no gas generation and utilization in 13 plants in spite of having anaerobic reactors/digesters. One of the main problem faced in India is that the gas generated from the treatment options are either not enough or flared or not utilized to be used as a fuel to run gas engines or generators. Even after construction of digesters, procurement of gas engines/generators, the quality of the gas produced doesn't help them to get power in most of the STP sites in India. This demands for alternative resources for power generation not affecting the eco-system at the same time.

And in a developing country like India, the resources and energy consumed are relatively high in the present built environment consequently leading to greater impacts to the ecosystem (Horvath, 2004). Therefore, globally as well as in India, there is a pressing need to accelerate the development of advanced clean energy technologies to fight back the global challenges of energy security, climate change and sustainable development. Solar PV is a key technology option to realize the shift to a decarbonized energy supply and is projected to emerge as an attractive alternate electricity source in the future.

According to International Energy Agency Photovoltaic Power System Annual Report 2016, the cumulative installed capacity worldwide is about 300 GW in which close to 75 GW was installed in 2016 alone accounting 50% above than that of 2015. And that too, in a tropical country like India where there is a longer duration of sunshine having about 300 sunny days in a year, there is greater potential to harness Solar Energy for operation (Srivastava & Srivastava, 2013). According to Ministry of Statistics and Program Implementation Government of India Report 2017, the total potential for solar power generation in the country is 748990 MW (62.48% of the total potential for renewable power generation in the country) as on 31.03.2016.

One of the study in Tough-Egypt tried to check the feasibility of Self-Sustained Waste Water Treatment plants by using solar Power by (Helal et al., 2013). However, the study is for completely self-sustained STP and Off-Grid applications where STP need not rely on electrical grid line at all. And study by Yifan et al. (2017) focusses completely self-sufficient wastewater treatment plants. But this study checks for the trade-off between the conventional grid power and solar Power to be used by the STP's operating with SBR technology and checking the feasibility of using On-grid Solar power for operating STP's considering both technical and financial figures.

The objectives of this study are as follows: a) estimating the maximum energy for which Solar PV system should be designed for STP's b) Fixed tilt PV sizing for the STP's c) perform Life Cycle Cost Analysis of the Solar PV to estimate the financial benefits out of the project

The study starts with the brief introduction of case study followed by research methodology adopted and then by the technical and financial analysis performed finally followed by the results of maximum PV array sizing, financial analysis, life cycle assessment ending with summary and scope of future work.

3. CASE STUDY

Rajasthan is India's largest state by area which comprises 10.4 % of India's total area. For the past few years, many wastewater projects have been commissioned in Rajasthan.

This study considers recent ongoing 4 STP projects with capacity 1.5 MLD, 2 MLD, 3 MLD, 8 MLD located in Rajasthan. The main intent of this selection is to check the feasibility of using solar energy for small capacity sewage treatment plants with capacity less than 10 MLD. The influent and desired treated sewage is same for all the 4 STP's. The influent raw sewage characteristics are given in Table 1. The treated sewage characteristics are given in Table 2. The abbreviations are expanded and given in Appendix 1.

Table 1: Influent Raw Sewage Characteristics

S.No.	Parameter	Unit	Value
1	BOD_5 (at 20^0C)	mg/l	300
2	COD	mg/l	650
3	TSS	mg/l	650
4	TKN (as N)	mg/l	55
5	TP	mg/l	6
6	pH	mg/l	6 to 9

Table 2: Treated Sewage Characteristics

S.No.	Parameter	Unit	Value
1	BOD_5 (at 20^0C)	mg/l	< 10
2	COD	mg/l	< 50
3	TSS	mg/l	< 10
4	NH4-N	mg/l	< 5
5	N Total	mg/l	< 10
6	Total Phosphorus	mg/l	< 2
7	Fecal Coliform	MPN /100 ml	< 100

3.1. TREATMENT SCHEME OF SBR BASED STP'S

The treatment scheme broadly consists of the following unit operations & processes:

1. Inlet chamber of STP
2. Screening – Mechanical & Manual Fine Screens
3. De-gritting – Mechanical & Manual Grit Chambers
4. Biological treatment - Sequential Batch Reactors (SBR)
5. Disinfection – Chlorination
6. Sludge management - Gravity Thickening and Mechanical Dewatering

The raw sewage is received in the inlet chamber and passed through mechanical fine screen and grit removal chamber. It is biologically treated in the SBR and then disinfected by chlorination. The surplus sewage sludge is subjected to thickening by gravity thickener and mechanical dewatering using centrifuge to remove excess water content before safe disposal (Gupta & Singh, 2012)

3.2. SCOPE OF THE STUDY – INCLUSIONS AND EXCLUSIONS

The raw sewage pumping station and treated sewage pumping is excluded from the study. All the electromechanical equipment's inside the sewage treatment plant is included for the study. Ventilation and Air-conditioning is excluded from the study. TRINA Solar TSM-320PD14 (320 Wp) polycrystalline silicon solar PV panel is selected for the study. The solar PV panels are assumed to work ideally. The tariff order issued by the Rajasthan Electricity Regulatory Commission for the year 2017-18 is considered for economic analysis of the solar PV's which includes the local and national taxes corresponding to Indian market. The service life of solar panels is taken as 30 years.

3.3. HOURLY ELECTRICAL LOAD PROFILE OF THE STP'S

The Solar PV system is grid connected and the electrical energy generation will be only required from 6 AM to 6PM when solar energy can be harnessed and used. The Electrical hourly load variation from 6 AM to 6 PM for all the 4 STP's were recorded and the summary is listed in Table 3.

Table 3: Electrical Hourly Load List Summary for the STP's from 6 A.M. To 6 P.M.

Summary	**1.5 MLD (kW)**	**2 MLD (kW)**	**3 MLD (kW)**	**8 MLD (kW)**
Total Consumption from 6 A.M. to 6 P.M. in terms of kWh	458.09	603.35	796.69	1860.02

4. METHODOLOGY

Sample of Sewage Treatment Plants (STPs) in Rajasthan in India is analyzed for the Techno-Economic Feasibility. The following field data are required from sewage treatment plants operating with SBR technology to design and analyse the solar PV powered STP.

1. Total power consumption details
2. Hourly electrical load profile
3. Topographical details of the location
4. Solar insolation levels at the location
5. Total land area occupied

Solar PV system is sized for grid-tied to arrive at the final capacity of the solar PV power plant. Life cycle cost analysis is the research methodology adopted for performing financial analysis.

Life cycle stages of the solar PV power plant covers the following stages which includes primarily production of raw materials, processing and purification, manufacture of modules and balance of system (BOS) components, secondly, transportation of the modules to the power plant, thirdly, installation and use of the systems and finally decommissioning and disposal or recycling. The decommissioning and disposal or recycling has not been considered in this study because of lack of reliable history of data.

4.1. FINANCIAL ANALYSIS

Investment in solar energy is not different from any other area of financial management. Financial analysis of solar PV system follows a similar procedure indifferent to any other investment. So, when the organization first decides to invest in solar energy, it should check the feasibility of the System by checking some of the significant financial figures.

The basic financial figures that should be estimated to check the feasibility include the following:

1. Simple payback period (SPBP)

SPBP refers to the time in number of years that is required to recover the initial investment considering only the net annual saving. SPBP is influenced only by the net cash flow of the system and the total service life. SPBP is calculated using following equation:

SPP = Project cost / Annual cash inflows (without considering the time value of money) Eq. (01)

2. Discounted payback period (DPBP)

DPBP represents the time in number of years that is required to recover the initial investment considering the time value of money. DPP is influenced by the net cash flow of the system and the total service life similar to SPP but along with the discount rate considering time value of money. DPBP is calculated using the following equation:

DPBP = Project cost / Annual cash inflows (considering time value of money) Eq. (02)

3. Net Present Value (NPV)

NPV is the difference between the present value of cash inflows and the present value of cash outflows. NPV is used in project capital budgeting to analyze the profitability of an investment. NPV analysis is sensitive to the reliability of future cash inflows that an investment will yield. For a project to be profitable or at least feasible, NPV should always be greater than zero or positive. Projects with negative NPV is not financially profitable. NPV is determined using the following equation:

$$NPV = \sum CF_t / (1 + K)^t, \; t = 0 \text{ to } n \qquad \text{Eq. (03)}$$

where
CF_t = Net cash flow occurring at the end of year (t = 0, 1,…. n)
n = life of the project in years
K = Discount rate

4. Internal Rate of Return (IRR)

IRR refers to the discount rate used at which the NPV of a particular project is equal to zero. A higher IRR indicates that it is more desirable to undertake the project. Hence, IRR is used to rank alternate project execution scenarios and the scenario with highest IRR is considered as the best possible option to undertake. IRR is sometimes referred as "economic rate of return" (ERR). IRR calculates the rate of return that an investment is expected to yield. IRR is determined using the following equation.

$$0 = \sum CF_t / (1 + IRR)^t, \; t = 0 \text{ to } n \qquad \text{Eq. (04)}$$

where
CF_t = Net cash flow occurring at the end of year (t = 0, 1,…. n)
n = life of the project in years

4.2. LIFE CYCLE COST ANALYSIS (LCCA) COMPONENTS

LCCA is the scientific methodology adopted for the financial analysis which includes the following components.

1. Initial cost (Expense)
2. Replacement cost (Expense)
3. Operation and Maintenance cost (Expense)
4. Incentive from government (Revenue)
5. Salvage value (Revenue)
6. Savings from power generation (Revenue)

Following list gives the detailed inclusions and exclusions in the LCCA components of the study

- Initial Cost

Design, Engineering and Management (DM) cost is considered (Tidball et al., 2010)

The tariff order issued by the Rajasthan Electricity Regulatory Commission for the year 2017-18 is considered for fixing the initial cost of the solar PV's along with the DM cost

- Replacement Cost

Inverters usually come with the service life of 25 to 30 years and 10%-part replacement is done every 10 years (Fthenakis et al., 2011). But based on actual practice, most of the inverters get replaced every 5 years because of lack of maintenance. So, inverter replacement every 5 years is considered for the study.

- Operation and Maintenance Cost

Operation and Maintenance cost considered is 11.68 USD (748.64 INR.) per kW per year (Tidball et al., 2010)

- Incentive from the Ministry of New and Renewable Energy (MNRE)

No Subsidy from MNRE for installing solar Panels for Government buildings, Government institutions, Private, Commercial and industrial sector

- Salvage Value

Maximum Salvage value at the year of 2010 for Crystalline PV cells are \$0.33 (Rs. 21.15). Most of the PV cells are imported and so this value shall be taken for the analysis (McCabe, 2011)

- Savings from power generation

The Unit cost of power is taken as 6.5 INR, i.e. 6.5 INR/kWh and practical observable degradation in India of 5% is considered in the first 5 years and then on 0.5% degradation of solar panels power is considered for consecutive years

4.3. SOLAR PV - LIFE CYCLE ASSESSMENT IN COMPARISON WITH FOSSIL FUEL POWER PLANTS IN INDIA

While there are no global warming emissions associated with generating electricity from solar energy, there are emissions associated with other stages of the solar life-cycle, including manufacturing, materials transportation, installation, maintenance, and decommissioning and dismantlement. The following are the system boundaries for life cycle assessment of Solar PV.

- The combination of PV module manufacturing, material for Balance of System (BOS) and PV energy production have been considered for the system.
- Mining of raw material is not included in the analysis
- All transportation steps are excluded (Assuming the Transportation influence is negligible compared to Manufacturing and Operation Cycle)
- Due to the lack of reliable data, recycling has not been taken in account (Mason et al., 2006)

Some of the important terminologies used are described below:

Energy Pay Back Period (EPBP)

EPBP is a measure of how long Energy mitigating process needs to run to compensate the Energy consumed during the life cycle stage.

EPBP = Energy consumed by solar plant (MWh)/Energy produced by Solar Power plant per year (MWh)

Carbon Payback Period (CPBP)

CPBP is a measure of how long a CO_2 mitigating process needs to run to compensate the CO_2 emitted to the atmosphere during the life cycle stage.

CPBP = (Life cycle CO_2 emission / Gross CO_2 emission avoided per year) x 365

The energy consumed for producing one poly-crystalline PV module is taken as 0.4464 MWh and the CO_2 emission by the production of one poly-crystalline PV module is taken as 71.49 kg (Marimuthu & Kirubakaran, 2013).

5. RESULTS AND DISCUSSIONS

5.1. MAXIMUM PV ARRAY CAPACITY

According to Solar-Radiation data from Meteonorm database (Meteotest, 2017) average annual horizontal radiation in the specified location in Rajasthan is 5.51 kWh/m^2/day. The maximum radiation can be obtained by tilting the surface at an optimum angle, which is determined by the latitude of the location and further considering inter-row gap of arrays.

Solar PV panels are installed at optimum tilt of 25.3 degree which is the latitude of the location as per "Performance from Solar Panels in India" submitted to Central Electricity Regulatory Commission, New Delhi

The average Annual Tilt radiation with respect to the tilt angle of 25.3^o is 6.07 kWh/m^2/day

Considering the average annual tilt radiation with Performance Ratio of the solar panels as 0.8, module efficiency as 15% and 5% degradation in the power generation at the end of 5 years, the maximum PV sizing for all the 4 STP's were arrived and the summary of the results is shown in Table 4.

Table 4: Maximum PV Array Capacity for the 4 STP's

STP Capacity (MLD)	Maximum PV array capacity (kWp)
1.5	99.0
2.0	131.0
3.0	172.0
8.0	403.0

5.2. *LIFE CYCLE COST ANALYSIS*

Based on the PV array capacity determined, LCCA was performed keeping into considerations listed under LCCA components earlier according to the tariff order issued by the Rajasthan Electricity Regulatory Commission for the year 2016-17.

The results of the LCCA is summarised in Table5. IRR and DPBP is estimated with the discount rate of 10%

Table 5: LCCA Results for The PV Array Capacity Installed at All The 4 STP's.

STP Capacity (MLD)	NPV (Million INR)	IRR (%)	SPBP (years)	DPBP (Years)
1.5	3.77	18.5	5.4	7.9
2	4.99	18.5	5.4	7.9
3	6.56	18.5	5.4	7.9
8	15.37	18.5	5.4	7.9

The SPBP and DPBP values are independent of the capacity of the STP's because of the similar characteristics of the STP's and selected PV modules.

5.3. *LIFE CYCLE ASSESSMENT IN COMPARISON WITH FOSSIL FUELS*

Because of the similar characteristics of the selected STP's and Solar PV modules, the EPBP and CPBP results do not vary with capacity of the STP's. The summary of the EPBP, Carbon emissions per unit generation of the solar PV plant and CBPB for the 1.5 MLD STP is given in Tables 6, 7 and 8.

Table 6: Energy Payback Period for the Solar PV Power Plant Estimated for 1.5 MLD Capacity STP

Capacity (kWp)	Avg. radiation ($kWh/m^2/day$)	Power generation (MWh per year)	Total Power consumption for producing Solar PV (MWh/Plant)	EPBP (years)
99	6.07	167.20	265.16	1.6

Table 7: Carbon Emission Per Unit of Power Generation of The Solar PV Power Plant For 1.5 MLD Capacity STP

kg CO_2 emission per kWp	Total capacity (kWp)	kg CO_2 emission for PV	kg of CO_2 emission for BOS	Total kg of CO_2 emission	Total power production per year (MWh)	Life time production (MWh)	CO_2 intensity (kg/MWh)
428.94	99	42,465.06	17954.64	60,419.70	167.20	5016.08	12.0

Table 8: Carbon Payback Period for The Solar PV Power Plant For 1.5 MLD Capacity STP

kg CO_2 emission per MWh	Carbon emission of coal-based power plant (kg CO_2/MWh)	Carbon reduction (kg/MWh)	Life cycle CO_2 emission (kg)	kg of CO_2 reduction per year	CPBP (Days)
12.0	941	933.0	60,419.70	155,323.89	142

The CO_2 emissions of solar PV comes around 8 kg/MWh of electricity produced while it is 941 kg/MWh for coal-based power plant in India. The result also shows that the EPBP of Solar PV is less than a year with CPBP of just 94 days which is a huge advantage environmentally in comparison with conventional coal-based power plants. The CO_2 emissions reduction by using solar PV panels to operate STP's in the complete lifetime is huge making it highly eco-friendly and the summary is shown in Table 9.

Table 9: CO_2 Emissions Reduction by Using Solar PV Panels to Operate STP's In the Complete Lifetime of the Panels

STP Capacity (MLD)	CO_2 emissions reduction (metric tonnes)
1.5	4660
2.0	6138
3.0	8104
8.0	18,921

6. SUMMARY

This study presents the ideal estimate of maximum solar power than can be utilised by the Solar PV for different capacity STP's less than 10MLD which can be used as reference in planning future projects. The results also show us that the kWh/MLD that can be generated with Solar PV reduces with increase in the capacity of STP. This study helps us to know that using on-grid Solar PV system for power generation in STP's with capacity less than 10 MLD is highly feasible both technically and financially. The yield or the rate of return is greater than 18% which gives enough propel for executing this in near future. The simple and discounted pay back periods fall less than 8 years which is considerably very less than the entire lifetime of the Solar PV as well as the STP which is normally 30 years. And also, the Life Cycle Assessment results shows that Solar PV is highly environment friendly with very less EPBP and CPBP in comparison with coal-based conventional power plants. This project Study, if executed, industries which bid for STP construction can not only place their foot-print on a hallmark project bridging the gap between STP and Solar Power but also can get along in winning the bid by virtue of the Power Guarantee. (Power Guarantee is a document to be given by the bidder along with the bid documents guaranteeing that the treatment plant will only take the specified units of power from the grid after which the contractor is liable for penalty for each unit consumed by the plant which poses huge risk in the longer run to the contractor bidding). Thus, project outcome encourages trying out power generation through solar PV to operate STP's which will make the country march on to sustainable construction practices along with financial profitability leading the future generation to have a sustainable future.

7. SCOPE OF FUTURE WORK

The current study only deals with STP's with capacity less than 10 Million Litres per Day and lot of other detailed studies can be to check the feasibility of using Solar PV for higher capacities. The challenge is, most of the STP's differ in their electromechanical components when the capacity is increased. Normalising into one category like this study may be little tedious when the capacity of STP is increased. Also, different type of Solar PV system also can be used as a variant from the fixed-tilt and the results can be compared. Thus, keeping in mind the trend of renewable energy and its applications in the present world, there is huge scope of improvement and research that can improve the technical and financial benefits of the Solar PV installed in STP's.

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APPENDIX 01

The list of abbreviations used are given below:

BOD	Biological Oxygen Demand	MW	Megawatt
CO_2	Carbon di-oxide	MWh	Megawatt hour
COD	Chemical Oxygen Demand	NH4	Ammonium
CPBP	Carbon payback period	NPV	Net Present Value
DPBP	Discounted payback period	pH	power of hydrogen
EPBP	Energy payback period	PV	Photovoltaic
GW	Gigawatt	SBR	Sequential batch reactor
IRR	Internal Rate of Return	SPBP	Simple payback period
kg	Kilogram	STP	Sewage Treatment Plant
kW	kilowatt	TKN	Total Kjeldahl Nitrogen
kWh	kilowatt hour	TP	Total phosphorus
LCC	Life Cycle Cost	TSS	Total suspended solid
MLD	Million litres per day	Wp	Watt peak

TENDENCY OF SRI LANKAN CONSTRUCTION ORGANISATIONS IN ADOPTING ENTERPRISE RESOURCE PLANNING SYSTEMS

K.G.G.D.V. Silva, Vijitha Disaratna and R. Dilakshan*

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

The popularity of Enterprise Resource Planning (ERP) system is increasing in many industries. Many researchers have conducted studies on ERP in relation with construction industry as well. The observations of some of the researches were contradictory, while most of them are observing positive tendency among the contractors. Nevertheless, the tendency of Sri Lankan contracting organisations to implement ERP systems has not been studied. Hence, this research aimed to find the tendency of Sri Lankan contracting organisations to implement ERP systems.

A mixed research approach along with an extensive literature review has been carried out to pursue the aim of this research. The concept of ERP has been identified along with the driving and restraining factors in implementing ERP system to contracting organisations.

It has been identified that ERP system is popular among the Sri Lankan construction industry professionals since most of them at least heard about the system. Nevertheless, as per the conclusion, even though there is a positive tendency among global contractors to implement ERP system to their organisations, Sri Lankan contracting organisations are still lacking in confidence to implement the system.

Keywords: *Construction Industry; Driving Factors; Enterprise Resource Planning (ERP); Restraining Factors.*

1. INTRODUCTION

Providing accurate information in timely manner within the organizations is a long remaining challenge (Monk & Wagner, 2009). To maintain the competitive advantage for a longer period the integration of operation flows are necessary, while fully utilizing information technology and scarce resources of the organization (Tamboycers, 2012). In addition, Sutar et al. (2016) stated that proper management of resources is vital for the success of the companies irrespective of being external or internal.

Estébanez et al. (2016) depicted that to uplift the management, performance and competitiveness; the companies now have a trend to implement their systems based on the information and communication technologies. Klaus et al. (2000) emphasised that Enterprise Resource Planning (ERP) is a comprehensive software package, which seeks to integrate the total array of business process and its functions. Standardisation and synchronisation of information is the basic philosophy behind ERP (Chung et al., 2008).

According to Ahmed et al. (2003), construction industry is a highly fragmented industry due to its project-based structure. Consequently, projects have resulted in poor productivity improvement within the industry (Sutar et al., 2016). Al Marri (2014) mentioned that project-based businesses must implement innovative technologies to survive in the market. On the other hand, ERP is used by construction firms to improve the ability of decision making, reduce the project time, reduce the data redundancy, minimise cost, improve quality and system integrity (Kadoli et al., 2014; Sutar et al., 2016; Al Marri, 2014). Nevertheless, Yang et al. (2007) have mentioned that the implementation of ERP to a firm require enormous investments in respect of time, money and resources. Thus, implementation of ERP must be carried out in a careful manner.

*Corresponding Author: E-mail – dilakshanrajaratnam@gmail.com

According to Chung (2007), many engineering sector companies hesitate to implement an ERP system even though they are well aware of the benefits they could reap out through implementation. Lee and Lee (2017) specified that there is a gap between the construction firms' need and the offered service of information technology companies. Ahmed et al. (2003) have mentioned that the researches on implementation of ERP in construction industry are very few. Particularly for contracting organisations, this fact is even stronger. Even though several researchers have conducted researches on ERP and construction companies in global context, the absence of researches on tendency of ERP implementation in Sri Lankan context has produced this research gap. Hence, this research aimed to identify the tendency of Sri Lankan construction organisations in implementing ERP systems.

2. LITERATURE FINDINGS

2.1. ENTERPRISE RESOURCE PLANNING

ERP is one of the greatest inventions in Information Technology (IT) industries in 1990s (Al-Mashari, 2002). It is a set of software packages, integrated and designed to manage business processes (Shehab et al., 2004). Kumar and Van Hillegersberg (2000) defined ERP as an adaptable software, which has been designed to integrate information and information-based processes of an organisation. Furthermore, Choudhury (2009) has stated that ERP is a commercial software suite, which integrates modular software applications so that the functions of an enterprise will be in accordance. ERP helps an organisation to run its functions under a common database by automating and integrating all business processes of the departments (Vlachopoulou & Manthou, 2006; Jackson, 2010). According to Bathorpe et al. (2004), these predecessors of ERP were known as material requirement planning (MRP) and manufacturing resource planning (MRPII). MRP had been used to ensure the material and capacity to be in accordance with the master plan, while MRPII, which had been evolved from MRP, used to integrate the manufacturing process. Chen (2001) has identified the key deviation of ERP from MRPII is the planning and scheduling of the supplier resources in consumer perspective.

2.2. ERP IN GLOBAL CONSTRUCTION INDUSTRY

Nowadays, construction industries seeking solutions from IT to solve the issues caused due to its fragmentation (Nitithamyong & Skibniewski, 2004). The literature has identified several key ERP vendors; SAP, Oracle, PeopleSoft, JD Edwards, Microsoft Dynamics, Infor ERP and Baan (Łobaziewicz, 2015; Al Mari, 2014; Tatari et al., 2008; Shehab et al., 2004; Tarn et al., 2002; Mabert et al., 2000; Klaus et al., 2000). According to Klaus et al. (2000) and Shehab et al. (2004), SAP, Oracle, JD Edwards, PeopleSoft and Baan are considered as "Big Five" of ERP market with more than 70% of the market share. However, these systems are originally intended to manufacturing industry and not primarily to the construction industry, therefore these vendors failed to reach construction industry (Tatari et al., 2008; Shi and Halpin 2003).

According to Shi and Halpin (2003), construction industry based ERP systems need to assist effectively the construction industry-based functions; project-based estimating, scheduling, planning, procurement etc. Subsequently, major ERP vendors SAP and Oracle invented construction-based ERP systems keep considering market saturation of the industries (Tatari et al., 2008). They have named these construction specific ERP systems as C-ERP which are different from the basic ERP systems. Nevertheless, some of the construction functions are still in the infant stage (Chung, 2007). However, adapting and integrating advanced technologies are essential for the fragmented industries while focusing and developing specific solutions (Al-Marri, 2014; Chung, 2007).

2.3. DRIVING FACTORS OF CONSTRUCTION COMPANIES TO ADOPT ERP SYSTEMS

Even though the implementation percentage of ERP in construction companies are low, according to the views of certain researches, it is certainly rising. For such increase in the popularity of the system, there must be certain driving factors or clear objectives to implement the system in contracting organisations. The following Table 1 represents the identified driving factors.

Table 1: Driving Factors of Construction Companies to adapt ERP

	Driving Factors	Al-Marri (2014)	Ahmed et al. (2003)	Sutar et al. (2016)	Tarn et al. (2002)	Hadidi et al. (2017)	Choudhry (2009)	Tambovcevs (2012)	Xu et al. (2006)
D1	Improvement of customer responsiveness	✓	✓	✓					✓
D2	Strengthening of supply chain partnerships	✓	✓	✓					✓
D3	Enhancement of organizational flexibility	✓	✓	✓		✓	✓		
D4	Improvement of decision-making capabilities	✓	✓	✓	✓	✓	✓		
D5	Reduction of working capital					✓	✓	✓	✓
D6	Reduction of project completion time and cost	✓	✓	✓		✓			
D7	Reduction of data redundancy	✓		✓				✓	
D8	Improvement in quality						✓		
D9	Just in time information/ real time data				✓			✓	
D10	Efficient communication	✓		✓	✓		✓		✓
D11	Improved user satisfaction					✓			
D12	Increased global competitiveness	✓			✓		✓	✓	✓
D13	Business efficiency					✓		✓	
D14	Economy of Resources							✓	✓
D15	Higher utilisation of employees				✓			✓	

2.4. *Restraining Factors of ERP Implementation in Construction Industry*

Restraining factors of ERP implementation in construction industry are hardly found. However, Momoh et al. (2010) have identified critical failure factors (CFF) of ERP implementation in general, which are cited by several researchers. The author considers CFF as restraining factors for this study, since cause of failures also are reasons for reluctance of implementation. The following Table 2 represents the identified Restraining factors (CFF).

Table 2: Restraining Factors of ERP Implementation in Construction Companies

	Restraining Factors (CFF)	**Number of Instances cited in Literature**
R1	Excessive customisation	13
R2	Dilemma of internal integration	8
R3	Poor understanding of business implications and requirements	7
R4	Lack of change Management	12
R5	Misalignment of IT with the business	9
R6	Hidden costs	3
R7	Limited Training	3
R8	Lack of top management support	4
R9	Poor data quality	5

(Adapted from: Momoh et al., 2010)

3. RESEARCH METHODOLOGY

This research was initiated with a literature survey to review the concept of ERP system. Thereafter, the driving (objectives) factors of ERP identified specifically to the construction industry and restraining (CFF) factors were identified in general. Based on the comprehensive literature review and the background study, following research problems were developed.

- How far are the Sri Lankan construction professionals aware of the ERP system?
- Who are the most popular ERP vendors among the Sri Lankan construction industry professionals?
- What is the impact of the driving (objectives) and restraining (CFF) factors identified through literature on implementing ERP systems to the Sri Lankan construction industry?

According to Pinsonneault and Kraemer (1993) out of the two main research approaches, quantitative approach tends to relate more towards the positivism than interpretivism. Nevertheless, according to Fellows and Lui (2003), the qualitative approach assists the researcher in studying beliefs, understandings, opinions and views of people. Since, in the research it is required to understand the experience of individuals in relation with the ERP usage, a mixed approach was taken.

In order to validate the findings of the literature to the Sri Lankan context a preliminary interview was conducted among five (05) IT professionals who possess experience of at least one ERP implementation in construction companies. Then 75 questionnaires were distributed among construction industry professionals based on the purposive sampling method to rate the effect of the driving and restraining factors on ERP implementation in relation with construction organisations to understand the tendency of ERP implementation in such organisation. Out of the 75 distributed questionnaires, only 35 were returned by giving a hint on the exposure of construction industry professionals on ERP systems. The following Table 3 shows the details of respondents.

Table 3: Details of the Questionnaire Survey Respondents

Designation	**Work experience (Years)**					
	0-5	6-10	11-15	16-20	More than 21	**Total**
Directors	-	-	02	01	01	**04**
Engineers	01	02	01	01	01	**06**
Quantity Surveyors	02	04	05	02	01	**14**
Accountants	**-**	04	03	02	02	**11**
Total	**03**	**10**	**11**	**06**	**05**	**35**

The respondents of the questionnaire were asked to rate the effect based on five point likert scale, “3” being considered as moderate value. Thereafter collected data were analysed based on Relative Importance Index (RII) using MS Excel. In addition, one tailed t tests was done to evaluate the validity of the sample with the population. Thereafter a force field analysis was done to assess the tendency proposed by Kart Lewin (Burnes, 2004).

4. RESEARCH FINDINGS AND DISCUSSION

4.1. *AWARENESS OF SRI LANKAN CONSTRUCTION PROFESSIONALS ON ERP SYSTEMS*

Five options were given to the respondents to rank their familiarity on ERP systems. Table 4 represents the level of ERP awareness among Sri Lankan construction professionals. As per the survey respondents, 86% of professionals have heard of the systems. Notably, 57 % of respondents are practicing ERP in their organisations and 6% of respondents are hoping to implement ERP systems. This shows a positive impact on ERP among Sri Lankan construction.

Table 4: Level of ERP Awareness

Level of Awareness	Percentage
Using an ERP System	28 %
Have used an ERP system	29 %
Hoping to implement an ERP system	06 %
Heard of ERP systems	23 %
Never heard of ERP systems	14 %

4.2. POPULARITY OF ERP VENDORS AMONG SRI LANKAN CONSTRUCTION PROFESSIONALS

To identify the most popular ERP vendor in Sri Lankan construction industry, the respondents were asked to rank the popularity of ERP vendors based on their familiarity. The following Table 5 represents the popularity percentage of ERP vendors. SAP is the most popular ERP vendor among Sri Lankan construction with 30 % of popularity percentage among eight (08) vendors. Proprietary and J.D Edwards are second and third popular vendors with 17% and 13% of popularity percentage. Oracle, Microsoft dynamic and BAN are ranked fourth popular vendor with 10 % of popularity percentage. However, People soft is not a considerable level of popular in Sri Lankan construction.

Table 5: Popularity of ERP vendors in Sri Lanka

ERP vendors	Popularity percentage
People soft	03 %
Infor ERP	07 %
Oracle	10 %
Microsoft dynamics	10 %
BAN	10 %
J. D. Edwards	13 %
Proprietary	17 %
SAP	30 %

The literature review identified a gap between construction companies' service requirement and offered service of IT companies, this fact is justified to the Sri Lankan context as well. Whereas, SAP is identified as the most popular vendor in the global context also. Notably, SAP has developed their custom made C-ERP systems (Tatari et al., 2008).

4.3. THE TENDENCY OF CONTRACTING ORGANISATIONS IN IMPLEMENTING ERP SYSTEM

The identified literature on the driving and restraining factors of ERP were validated to the Sri Lankan construction industry through a preliminary interview. All the interviewees agreed with the identified driving factors. In addition, the interviewees also agreed CFF as restraining factors of ERP implementation. In addition as per them, even though the restraining factors were identified in general, those restraining factors are common to the construction also. Moreover, the interviewees have suggested six (R10, R11, R12, R13, R14 and R15) additional restraining factors.

Thereafter, to identify the tendency of Sri Lankan contracting organisations on ERP implementation, the respondents were asked to rate the impact of each driving and restraining factor. Further, it has been processed with one tailed t tests and each factor received a value more than 0.05. Hence, with a confidence interval of 95%, all the factors including six additional factors found through preliminary interview are considered important in ERP implementation to the contracting organisations.

4.3.1. FORCE FIELD ANALYSIS

Driving and restraining factors of ERP were asked by the respondents of the questionnaire to rate against the impact during implementation process. Thereafter weight was calculated by multiplying the RII value by 10 and rounding off to the nearest whole number.

Total Weight of Driving Factors

Table 6 shows the weighted values of each driving factors. All the driving factors has got the RII value more than 0.5, therefore it can be said that, all the driving factors has got considerable level of impact in implementing ERP in contracting organisations. According to the participants, efficient communication (D10) considered as the highest driving factor and just in time information/ real time data (D9) perceived second highest driving value. However, customer responsiveness (D1) perceived the least weighted value (5) among all the driving factors. Nevertheless, since the weighted values of all the factors other than D1 are greater than 7, driving factors of ERP showing a positive impact on implementation.

Table 6: Total Weight of Driving Factors

	Driving Factors	RII	Weight
D1	Improvement of customer responsiveness	0.527	5
D2	Strengthening of supply chain partnerships	0.753	8
D3	Enhancement of organizational flexibility	0.707	7
D4	Improvement of decision-making capabilities	0.813	8
D5	Reduction of working capital	0.700	7
D6	Reduction of project completion time and cost	0.707	7
D7	Reduction of data redundancy	0.753	8
D8	Improvement in quality	0.833	8
D9	Just in time information/ real time data	0.860	9
D10	Efficient communication	0.887	9
D11	Improved user satisfaction	0.820	8
D12	Increased global competitiveness	0.760	8
D13	Business efficiency	0.843	8
D14	Economy of Resources	0.807	8
D15	Higher utilisation of employees	0.833	8
	Total Weight of Driving Factors		**116**

Total Weight of Restraining Factors

Table 7 shows the weighted values of each restraining factor. Lack of top management support (R8) considered as the extreme restraining factor. Excessive customisation (R1) and lack of change management practices (R 4) were considered as second and third restraining factors. However, poor data quality perceived weighted value of five (5), which is considered as the least restraining factor. On the other hand it could be said that ERP is an effective tool to ensure data quality.

Table 7: Total Weight of Restraining Factors

	Restraining Factors	RII	Weight
R1	Excessive customisation	0.860	9
R2	Dilemma of internal integration	0.667	7
R3	Poor understanding of business implications and requirements	0.780	8
R4	Lack of change Management	0.843	8
R5	Misalignment of IT with the business	0.793	8
R6	Hidden costs	0.840	8
R7	Limited Training	0.813	8
R8	Lack of top management support	0.867	9
R9	Poor data quality	0.527	5
R10	High implementation cost	0.840	8
R11	Inability of the system to thrive on little data available	0.760	8
R12	Unwillingness to share information	0.767	8

	Restraining Factors	RII	Weight
R13	Short term project time	0.667	7
R14	Unwillingness to move forward from traditional systems	0.767	8
R15	Time consumption for implementation	0.813	8
	Total Weight of Restraining Factors		**117**

Tendency = Weight of Driving Factors – Weight of Restraining Factors Eq. (01)

= 116 – 117

= **(-1)**

The result of the force field analysis shows that, the weight difference between driving and restraining factors were merely neutral. However, the literature identified, in other countries C-ERP systems has shown a positive impact to effectively assist the construction industry-based functions (Shi & Halpin, 2003). It is apparent that the construction organisations in Sri Lanka are still lack in confidence to implement ERP systems. Therefore, further studies has to be done in reducing the impact of restraining factors, whilst giving focus on increasing driving factors.

5. CONCLUSIONS AND RECOMMENDATIONS

The ERP system is a mean to automate and integrate all the functions of an organisation. It provides a central platform to carry out all the business activities within the organisation. ERP system being a huge and long-term investment to the organisations. Therefore, organizations tend to be reluctant in implementing it.

According to the interviewees, the ERP implementation is less in construction industries. The basic reason for this is, the ERP systems were not originally designed for construction industry and such system required major customisation with its unique characteristics.

The force field analysis was done based on Sri Lankan context. According to the results, Sri Lankan construction organisations are still lack in confidence to implement ERP systems. The construction companies still think the driving factors of ERP implementation are not enough to supersede the effect of restraining factors.

Therefore, it is recommended to reduce the effect of restraining factors identified in this research and make the path easier for ERP system to penetrate into Sri Lankan construction organisations. The major restraining factors identified are lack of top management support and excessive customisations needed for construction organisations. Therefore, the needs should be identified clearly with less customisation to get maximum support from the top management. On the contrary, the major ERP vendors need to develop systems with respect to the requirements of their clients instead of allowing them to customise.

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THE PROSPECT OF IMPLEMENTING PF2 IN SRI LANKA

T. Ravishker*, T.S. Jayawickrama and D.G. Melagoda

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

The Private Finance Initiative (PFI) as a sub-set of broader procurement approach of Public Private Partnerships (PPP), uses private sector capacity and public resources in order to deliver public sector infrastructure and/or services. In 2012, the UK Government publicly launched the new model, called "Private Finance 2 (PF2)" with some significant reforms to the PFI model, which are particularly aimed at tackling inefficiency, increasing transparency, shortening procurement periods and attracting new sources of finance. PF2 can be used as an instrument for producing new and more effective ways of bringing public services. While other countries are moving from PFI model to PF2 and other variants of PFI model, in Sri Lanka, there is a dearth of PFI type projects. However, there is a considerable number of researches on PFI model in Sri Lanka, but there is no evidence for researches on PF2 model. Accordingly, this is an initial study aimed to determine the prospect of implementing PF2 model in Sri Lanka. Applicability of PF2 model in the Sri Lankan context was defined using the collected through expert interviews and suitable sectors to implement PF2 model were ranked based on Relative Importance Index (RII) value. Construction industry advisors of the government and construction organizations who are either familiar and knowledgeable with the model were selected for data collection. Results show that the PF2 model is generally applicable in Sri Lanka compared to PFI features. Transportation, provision of electricity and water, and health care were recognized as the most suitable sectors to apply PF2 model in Sri Lanka. On the other hand, real estate and educational sectors have been recognized as sectors which are not suitable to carry out under the PF2 model.

Keywords: *Applicability; PFI; PF2; Sri Lanka.*

1. INTRODUCTION

Infrastructure investment and welfare outcomes of countries have a positive correlation in general (Asian Development Bank, 2005). Implementing public private partnership (PPP) as a model for private participation has become one of the utmost popular options worldwide in addressing concern over public resource scarcity in infrastructure delivery (Mahalingam 2010). Carbonara and Pellegrino (2014) highlighted that the period 2002 -2013 shows a growth in the PPP market compared to the public infrastructure market.

PPP projects are complicated and encompass many parties with conflicting purposes. Hence, PPP projects often require extensive expertise involvement, involve high costs and take lengthy negotiation time (Cheung et al., 2009). Li et al. (2005) contended private finance initiative (PFI) as the most dominant and well-documented model of PPP in the UK. Rising debt crisis and reduction of external borrowing capacity have compelled many developing countries to focus on PFI in infrastructure projects (Jefferies et al., 2002). PFI stipulates a method, advanced initially by the UK government, to provide monetary support for PPPs between the private and public sectors. Currently, this procedure has been adopted in numerous other countries as a part of a wider reform programme for the delivery of public services which is driven by the World Trade Organisation (WTO), International Monetary Fund (IMF) and the World Bank as a part of their deregulation and privatization drive (Ashworth et al., 2015).

Despite a range of benefits which can be gained through PFI contracts, there were some dissatisfactions exist in PFI projects such as slow and expensive process of procurement, inappropriate risk allocation, insufficiently

*Corresponding Author: E-mail – ravishker@gmail.com

flexible contracts during operational period, insufficient transparency and concerns about value for money (HM Treasury, 2012a). In 2012, PFI underwent a thorough review. Following a call for evidence, deviations were adopted to the model to improve transparency, value for money and partnership working and it was re-launched as Private Finance Initiative-2 (PF2) (HM Treasury, 2012b). The change came against the backdrop of the unpleasant experiences which have bedevilled the PFI model leading to huge public sector bail-out and sometimes costly buy-back schemes (Zawawi et al., 2014).

PF2 harness the key advantages of PPPs and remains to draw on private finance expertise. Bearing in mind of past issues in PFI, the PF2 model comprises a number of changes promoting a new form of partnership to accomplish improved provision of infrastructure. PF2 also responds to economic conditions in its approach to finance infrastructure (HM Treasury, 2012a). Considering of past issues in PFI, the PF2 model comprises a number of changes promoting a new form of partnership to accomplish better provision of infrastructure. Hence the need of the hour is to switch to PF2 in order to improve the efficiency in infrastructure development. The contention behind this change would be to promote greater efficiency and accountability in public sector projects in Sri Lanka. Despite a number of prior studies that have investigated the critical success factors (CSFs) of PPP/PFI projects in other countries, there seems to be a paucity of research effort on PF2 projects in developing economies. Therefore, in a nutshell, analysing the prospect of implementing PF2 model, offers some insights and useful information for government and private sector providers concerning the important factors that need to be emphasized in ensuring the successful implementation of PF2 model.

While other countries are moving on PF2 and other variants of PFI model, in Sri Lanka, PFI type projects are still lacking. PF2 can be used as an instrument for making new and more effective ways of bringing public services. Despite the researches done on PFI model in Sri Lanka, there is no evidence for researches on PF2 model. Accordingly, this study is aimed to determine the prospect of implementing PF2 model in Sri Lanka consolidated with the objectives to identify the characteristics, advantages and disadvantages of PF2 model and to identify the suitable sectors to which the PF2 model can be successfully applied in Sri Lanka.

2. LITERATURE REVIEW

2.1. *PUBLIC PRIVATE PARTNERSHIP (PPP)*

According to Reetika et al. (2015), in a competitive atmosphere, governments around the world are concentrating on new ways to finance projects; building infrastructure and deliver services. PPP seems to be an instrument to bring together the strengths of both public and private sectors. In order to maximize efficiency and innovation of private enterprises, PPPs can provide desired capital to finance government programs and projects, thereby releasing public funds for core economic and social programs. Hwang et al. (2013) pinpointed that following the 2007–2008 global financial crises there has been an increasing interest in the adoption of PPP policy by governments in both developed and developing countries.

Ismail (2013) stated that PPPs are a globally-accepted mechanism whereby government organizations utilize the skills and resources of the private sector, and shift responsibility for providing public services to private entities. According to Jefferies et al. (2002), many PPP projects in the UK and other developed economies are regarded as successful. Successful PPP projects are also reported in Hong Kong, Singapore, Australia and also it has become progressively common in India (Reetika et al., 2015).

2.2. *PRIVATE FINANCE INITIATIVE (PFI)*

PPP is the generic term for the development of projects including both public and private sectors, of which PFI is one variant (HM Treasury, 2000; Tang et al., 2010). The recent definition of PFI in the UK is, where the government enters into a long-term contractual arrangement with private sector companies, the latter undertaking to design, build and operate an asset, based on output specifications (National Audit Office, 2011). According to Wang (2014), PFI is a type of PPP that is the most dominant and well-documented model in the UK. In PFI model projects, the public sector outlines the requirements to meet public needs and ensures delivery of the outputs through the contract, while the private sector is harnessed to offer a better quality of public services (Wang, 2014).

Private Finance Initiative (PFI) is an alternative method of procuring public infrastructure by the private sector finance (Akintoye et al., 2003; Owen & Merna, 1997). PFI model projects involve highly leveraged capital structure in which the private sector is accountable to design, build, maintain and finance new infrastructure for a long term concession period, more than 25 years (Ismail, 2014).

2.3. *BENEFITS OF PFI MODEL*

As mentioned by Akintoye et al. (2003), there are many advantages of implementing PFI projects as they grant "value for money", reduce administration costs, transfer risk away from the public sector to the private sector, facilitate creative and innovative approaches, cap final service costs at predetermined levels, and reduce public money tied up in capital investment. The main purported advantages of PFI are improved efficiency, decreased inflation, reduced public sector expenditure and expanded private financing of capital projects (Chang et al., 2010). PFI projects are reported as mostly delivered on time and within budget, in comparison with traditional procurement (European Policy Forum, 2011). Fischer et al. (as cited in Wang, 2014) pointed out the main features of PFI as being risk-sharing, sharing task and responsibility, private investment, life cycle optimisation, innovation and long-term contractual partnerships. Owen and Merna (1997) pinpointed that having a private provider of a capital asset can enable public bodies to purchase services without the need for the initial capital investment.

2.4. *FAILURE OF PFI*

Although the PFI was introduced by the UK government in the hope to improve performance of the construction industry and to finance run-down public facilities, it has received increasing public criticism in recent years. The blames were focused on the cost-inefficiency, inflexibility (Heald, 2003) and managerial issues of the mechanism (European Policy Forum, 2011), such as the high competitive cost and the supply of available capital especially after the credit crunch in 2008. Furthermore, according to Handley and Gao (2003), another issue arises out of PFI is the cost of capital. Also in PFI contracts, the involvement of the main construction contractor is short relative to the duration of the PFI contract and therefore, there might be a tendency for the construction contractor to focus on initial construction costs rather than total life cycle costs, which would include future operational and maintenance costs (Swaffield & McDonald, 2008).

2.5. *PRIVATE FINANCE 2 (PF2)*

On 5 December 2012 the Government of UK published "A New Approach to Public Private Partnerships". This document sets out the policy conclusions of the Government's "Call for Evidence and review of PFI" and presents a new approach for connecting private finance in the delivery of public infrastructure and services (Pemberton & Pisanelli, 2013). PF2 has been developed to address the problems of past PFI model projects and to respond to the recent fluctuations in the economic environment, while retaining the advantage of private sector investment. Under the new approach, the private sector will continue to be responsible for designing, building, financing and maintaining an infrastructure asset over a defined period, typically, between 20-30 years (HM Treasury, 2012a). UK Government publicly launched the new model, PF2 and a revised guidance document entitled "Standardisation of PF2 Contracts" (Pemberton & Pisanelli, 2013). Despite some previous indications from those in government sector, that the PFI procurement model might be scrapped entirely, it was immediately clear that the basic structure of the PFI model had remained unscathed within PF2.

2.6. *SPECIFIC CHANGES AND BENEFITS OF PF2 OVER PFI*

According to HM Treasury (2012b), basically, issues from PFI and reforms from PF2 issues and reforms can split into seven areas as summarized in Table 1. Further, it illustrates specific changes in PF2 and benefits gained as a result of identified changes over PFI.

Table 1: Specific Changes and Benefits of PF2 over PFI

Specific Changes	**Benefits**
1. *Equity Finance*	
Increasing the equity funding requirement for PF2 schemes from around 10% to between 20% and 25%. The government taking a stake expected to be between 30% and 49% in the overall equity	Allocating the potential ‘upside’ of the return gained by the project company as well as the risk of the ‘downside’ of project company losses
Introduction of equity funding competitions.	It is predicted that this percentage of the debt should automatically be cheaper, which will assist with the affordability of the project.
2. *Debt Finance*	
Implementation of various measures to increase the credit rating of the project to encourage institutional investors/pension funds to participate.	Capital markets, whether public or private, have a deep pool of investors who are attracted to the relatively low risk infrastructure asset class.
Continues to encourage alternative financing sources including loan, guarantee and credit support products provided by commercial banks and other financial institutions.	Provides deleveraged capital structures, facilitated by public sector co-investment, combined with better risk allocation and the removal of certain operational risks which are expected to facilitate access to institutional investor capital.
3. *Greater transparency*	
PF2 introduces a range of measures designed around what is considered best practice in this area; ▪ the provision and maintenance of building and operating manuals, alongside regular service performance reports; ▪ maintenance of books of account recording costs, overheads, and other payments, including details of life-cycle funds on an open book basis. ▪ provision of ownership details including the price of any shares sold.	These measures will increase the transparency and accountability of privately financed PPPs and will be introduced in a proportionate way so as not unnecessarily to increase the burden of administration and cost of PF2 projects.
4. *Flexibility*	
“Soft” services (cleaning, catering etc.) to be removed and “call-of” provisions introduced or minor maintenance etc.	The range of services included in PF2 projects will be reduced to provide greater flexibility and efficiency.
5. *Procurement*	
Procurement to be routed through new centralised procurement units The competitive tendering phase of PF2 projects, measured from the issuance of project tender to the appointment of a preferred bidder, will not be allowed to take longer than 18 months.	Improve PF2 procurement to ensure it is faster and cheaper going forward, without sacrificing quality and competitiveness
6. *Risk Allocation*	
Take certain risks back to public sector to avoid private sector pricing inefficiently for these The greater retention and management of certain risks by the public sector, such as the risk of additional capital expenditure arising from an unforeseeable general change in law.	These changes are expected to lead to better value for money for the public sector, since the private sector will no longer need to include contingencies or reserves for such risks in their pricing model.
7. *Value for Money and Efficiency*	
Implementation of periodic reviews and requirement to tender proposals for continuous improvement	Changes may be made to the service scope to better suit the needs of the users or deliverability for the private sector and deliver savings for the public sector.

Source: HM Treasury (2012b)

2.7. SRI LANKA'S CURRENT POSITION ON PPP/PFIS

Being a small island nation, Sri Lanka needs to integrate with world economy by effective trade and investment policy to obtain required investment flows to the country (Ministry of Finance, 2016). According to Shashimal (2016), after many years of conflicts, the country is presently facing the challenge of reconstructing and expanding its key infrastructure services.

During the post-conflict period of 2009-2015, the government embarked on a fast public investment programme to address the long ignored infrastructure needs of the country that was hampered due to the conflict that prevailed. Nevertheless, for the government to occupy in these development on its own would require nearly a tripling of its public investment per annum (Ministry of Finance, 2016). This will however create significant imbalance due to the limited resources envelope of the Sri Lankan government.

Nonetheless, resource constraints are not unique to Sri Lanka alone, but is in general in many countries that is grappling with many demands on its limited resources. Wibowo and Alfen (2014) pinpointed that acute fiscal problems faced by many governments have also been widely reported to be the major constraint on both new development and on the upgrading of deteriorating infrastructure. Hwang et al., (2013) pointed out that PPP is an increasingly popular choice for policymakers in implementing important public works projects, especially in the face of a shortage of government financial resources and where it is necessary to counter public inefficiency. According to Babatunde et al. (2012), PPPs allow governments to mobilize and allocate private sector capital, technology and entrepreneurship efficiently and effectively, thus enabling governments to meet the responsibilities and the demands placed upon it by its citizens.

It is in this background that the Government of Sri Lanka announced in the Budget 2016, to utilize PPPs in its development strategy especially in urban development, expressways, power generation, and so on (Ministry of Finance, 2016). Nowadays the necessity of implementing PPP/PFI has been realized by Sri Lankan government. "Key Legal Reforms Identified in the Budget 2016" and Public Private Partnership Act are the good examples that show this realization (Ministry of Finance, 2016).

There is no evidence for PF2 type projects in Sri Lanka but other types of PPP models have been utilized in the country. According to Ministry of Finance (2016), Sri Lanka's experiences in PPPs are less in numbers such as South Asia Gateway Terminal Project (SAGT), Colombo South Container Terminal Development Project (SCT) and Colombo East Container Terminal Development Project. Despite government's realization of importance of PPP/PFI, satisfactory PPP/PFI model projects are lacking in the country.

3. RESEARCH METHOD

The research utilised both qualitative and quantitative methods for the purposes of data collection and analysis of the study. Literature was reviewed and synthesised on contemporary PF2 models around the world with special emphasis on UK to outline their structure and functions. Salient features of these PF2 models were superimposed to the Sri Lankan situation to form a comparison with the previous model. Since PF2 model is new to Sri Lanka, the knowledge and expertise of PF2 is limited. However, this study approached senior industry advisors who are either familiar with PPP implementation because they had expertise from overseas or are familiar with the intent and direction for PF2 adoption. Interviews were determined as the appropriate data collection technique since the researcher required to explain the PF2 features and to have a detailed discussion about this new model. Ten senior construction related professionals of government or construction organisations were identified as being for appropriate to interview and out of them, six respondents were from public organizations while four of them are from private organizations. Therefore, the sample can be considered as representative to obtain balanced opinions from both sectors. Experts' opinion was obtained on applicability of PF2 model to Sri Lanka compared to PFI considering their salient features. Collected data was analysed using manual content analysis technique. Eventually, most suitable sectors to apply PF2 in Sri Lankan context were analysed using relative importance index (RII). This study was carried out only to PF2 type procurement in Sri Lanka. Furthermore, Standardization of PF2 Contracts Draft, the publication of HM Treasury, UK, was taken as a standard model and any other models of PFI was not considered. It mirrors the new approach of contracting for projects for the delivery of infrastructure and services using PPP and substitutes "Standardisation of PFI Contracts".

4. DATA ANALYSIS FINDINGS AND DISCUSSION

4.1. RESPONDENTS' AWARENESS ABOUT PPP/PFI/PF2 MODELS

Respondents of the survey were construction professionals working across contracting, consulting, and client organizations in private and government sector at different managerial positions and having different experience in the construction industry. While only two respondents are having less than 10 years of experience, all others have above 15 years of professional experience, except one who has 10-15 years of experience. All respondents acknowledged that they had been experienced in different forms of PPP contracts to varying degrees. Therefore, the sample group can be considered as ensuring reliability of information obtained through the survey. Since PF2 is new in the Sri Lankan context, features of PF2 were explained and further questions were discussed during the interviews.

4.2. RESPONDENTS' ANSWER FOR SECTORS THAT ARE SUITABLE FOR PF2 MODEL

Table 2 shows respondents' view on the suitability of PF2 model in Sri Lanka in general and suitable sectors where PF2 model is to be applied.

Table 2: Respondents' View on Sectors Suitable for PF2 Model

Respondent	Sector Attached to	Experience	Is PF2 model suitable for SL	For which sectors
A	Construction	> 15 years	Yes	Transport, healthcare, education and real estate
B	Construction	> 10 years	Yes	Energy sector and transport
C	Construction	> 10 years	Yes	Provision of electricity, transport and water and sewerage treatment
D	Construction	> 10 years	Yes	Transport and environmental sector
E	Construction	> 20 years	Yes	Transport
F	Construction	> 15 years	Yes	Leisure and tourism
G	Construction	> 10 years	No	-
H	Construction	> 10 years	Yes	Healthcare, transport
J	Construction	> 10 years	Yes	Hospitals, roads and power sectors
K	Construction	> 10 years	Yes	Healthcare and road

Most of the respondents accepted that PF2 model is suitable for Sri Lanka except respondent G (as shown in Table 2) who claimed that because of the Sri Lankan politician's attitude, private parties are fear to invest in Sri Lanka. However, despite this common issue in many developing countries, interviews with experts revealed the applicability of PF2 model in Sri Lanka in general. Also, interviewees were asked for suitable sectors to adopt PF2 model as depicted in Table 2. Moreover, Figure 1 shows the mean score of the opinion of respondents with respect to types of projects which are suitable for the execution of PF2 model.

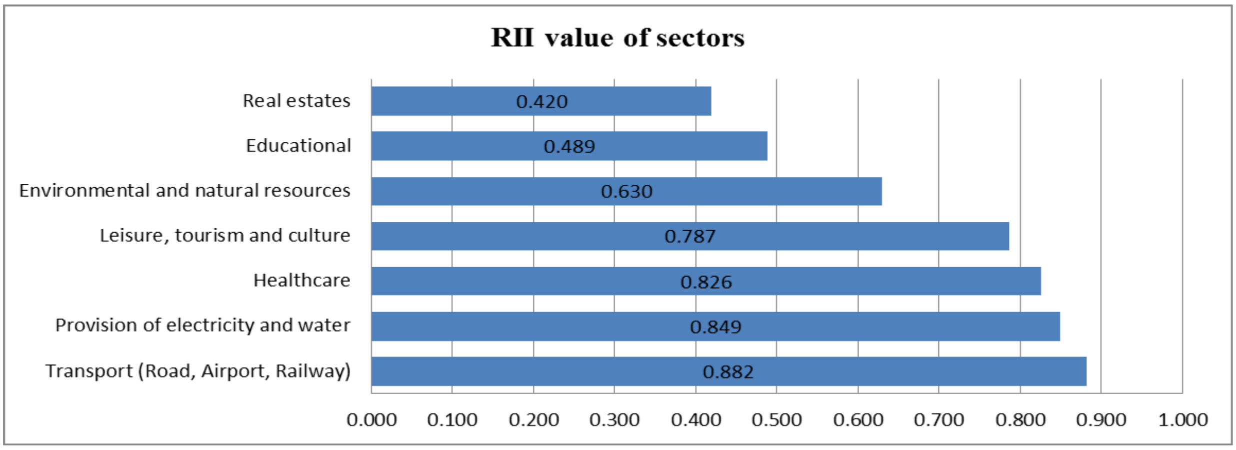

Figure 1: RII Values of Suitability for PF2 model

As per the overall opinion of respondents, transport, healthcare, environment, leisure and education are suitable sectors to adopt this model in Sri Lanka. Results show that transportation projects which include road, airport and rail construction were ranked highest with the RII value of 0.882, followed by provision of electricity and water with RII value of 0.849. This can be buttressed with the fact that these infrastructure projects are usually executed by the government or any private individual successfully without any assistance or intervention from a third party, corporation or individual. Real estate sector has the least RII value of 0.420. This can be buttressed with the fact that real estate sector is not a well-established sector in Sri Lanka yet. Historical data are very much vital for real estate sector. In Sri Lanka, it is tedious to obtain these historical data. So, private parties are not interested in Sri Lankan real estate market to invest individually or with the partnering of public party. Furthermore, education sector was the second least value of RII (0.489). This inference can be hinged on the fact that the projects involved in educational sector faced huge barriers in the form of protests for privatisation of education sector by a majority of Sri Lankan community. For instance, in the past recent, there were protests against a well-known private higher education institute in Sri Lanka which validates this result.

4.3. RESPONDENT'S VIEW ON SPECIFIC FEATURES OF PF2 OVER PFI MODEL

Table 3 illustrates the number of responses received for each category whether 'strongly agree', 'neither agree nor disagree' or 'strongly disagree' on the applicability of specific features of PF2 in the Sri Lankan context over PFI model.

Table 3: Respondents' View on Specific Features of PF2 over PFI Model

Feature No.	Specific Features of PF2 over PFI model	Response out of 10		
		Strong agreement	Neither agreement nor disagreement	Strong disagreement
F1	Increasing the equity funding requirement for PF2 schemes from around 10% to between 20% and 25%.	8	0	2
F2	The government taking a stake expected to be between 30% and 49% in the overall equity of PF2 projects.	7	3	0
F3	Introducing funding competitions for equity investors at the preferred bidder stage of procurement.	10	0	0
F4	Requiring authorities to consider the appropriate scope of the design requirements for the projects under procurement and maximizing value for money in relation to design.	10	0	0
F5	Introducing centralised procurement through departmental procurement oversight units to increase consistency and efficiency by the public sector.	3	5	2

Feature No.	Specific Features of PF2 over PFI model	Response out of 10		
		Strong agreement	Neither agreement nor disagreement	Strong disagreement
F6	Streamlining the procurement process by introducing a standardised procurement protocol and a comprehensive suite of standard procurement documents.	10	0	0
F7	Public sector will retain the entire capital spending risk for general change in law.	10	0	0
F8	The public sector is permitted to cover some risks during the services phase by way of indemnity where it has established a business case that this would provide better value for money than requiring the contractor to procure insurance.	10	0	0
F9	The government has retained “hard" services, but excluded "soft" services from the contract structure.	3	1	6
F10	There will be additional flexibility within the contract structure to add or remove certain "elective" services.	3	4	3
F11	The government has outlined a range of benefits arising from its proposal to act as a minority equity co-investor in future projects, and to participate in the governance of the project company through public sector directors who will be appointed to the board of the project company.	3	4	3
F12	Establishment of a Central Government Unit (CGU), for the purpose of making commercial investment decisions and managing the future portfolio of investments.	8	1	1
F13	The introduction of contract efficiency reviews throughout the life of the project on the basis that any savings are to be shared between the public sector and the project company. The guidance suggests that the public sector should take 75% of any savings with only 25% being retained by the private sector.	0	1	9
F14	Requiring the project company, as part of its services, to provide financial and other details on a regular basis to the public sector authority.	9	1	0

Fourteen major features were asked in order to identify whether the main features of PF2 model is suitable to the Sri Lankan context or not. As can be seen in Table 3, there is a conflict of opinions concerning feature F11. Respondents A, C and F positively claimed that this feature will enrich the transparency of the project and government can ensure the value for money by increased power. However equal amount of respondents strongly disagreed with this feature. All respondents agreed that feature F3; ‘increasing competition for equity investment at bidder stage’ will help to find most appropriate equity investors. None of the respondents stated that feature F13 ‘the introduction of clause of public sector will retain the entire capital spending risk for general change in law’, as an inappropriate suggestion.

According to the responses given by the construction professionals on special features of PF2 over PFI, most of them said that feature F8, ‘the public sector is permitted to cover some risks during the services phase by way of indemnity where it has established a business case that this would provide better value for money than requiring the contractor to procure insurance’.

Respondents A, D, F and J did neither agree nor disagree with ‘introducing additional flexibility within the contract structure to add or remove certain "elective" services’ (feature F10). Because they argued that this feature will make private party to fear to enter into contract because it can reduce their profitable area. For an instance, giving a particular service to a new contractor can reduce the profit of the existing contractor. Moreover, these respondents stated that developing countries like Sri Lanka are still lacking in attracting private parties to invest in PPP type projects. However, they agreed that this feature helps to increase value for money.

Most of the respondents neither agreed nor disagreed to the feature F5, 'introducing centralised procurement through departmental procurement oversight units to increase consistency and efficiency by the public sector'. Respondent E described the reason as this feature can reflect both positive and negative effect. Since this feature promotes the consistency and efficiency of the procurement process, but the nature of politicians will be a burden for project success.

5. CONCLUSIONS

Suitability of PF2 model in the Sri Lankan context was recognized to be positive through the interviews with experts and suitable sectors for implementing PF2 model were ranked. Accordingly, transportation (road, airport, railway), provision of electricity and water and healthcare sectors were recognized as most suitable sectors while real estates and educational sectors were recognized as not suitable.

Consequently, specific features of PF2 over PFI model were analysed to establish the suitability of PF2 in Sri Lanka. Positive feedback was received on features such as, 'introducing funding competitions for equity investors', 'requiring authorities to consider the appropriate scope of the design requirements for the projects under procurement and maximizing value for money in relation to design', 'streamlining the procurement process by introducing a standardised procurement protocol and standard procurement document', 'facilitating to cover some risks during the services phase by way of indemnity than requiring the contractor to procure insurance' and 'retaining the entire capital spending risk by public sector for general change in law'. Despite the negative feedback on the features in which the public sector should take 75% of any savings with only 25% being retained by the private sector', results show a general acceptance of PF2 model in Sri Lanka. Therefore, this initial study can be concluded with the fact that Sri Lanka will be benefited with implementation of PF2 model according to the view of majority of respondents.

The current study will be extended to analyse critical success factors (CSFs) for implementing PF2 model in developing economics since the identification of CSFs for construction projects enable appropriate decision making to achieve the project objectives. It will be benefited to enhance public infrastructure sector through efficient investments and procurement where there is no researches reported to-date on CSFs for implementing PF2 model.

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THE SIGNIFICANCE OF LABOUR FACTOR IN INTEGRATING SUSTAINABILITY CONCEPT INTO CONSTRUCTION INDUSTRY PRACTICE

K. Imansha Dushmanthi Kumarasinghe* and Chandanie Hadiwattege

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Sustainable Development (SD) has become a major consideration due to low responsiveness of industries to the natural environment and related social problems. The construction industry is a main natural resource consumer and a major contributor to country's economy. Hence, the sustainable performance of construction industry is essential to achieve SD goals. The construction industry is a labour incentive industry and therefore, the way construction works are planned, scheduled and controlled depends directly on the labours performance. This research is aimed to evaluate the influence of labour factor in integrating sustainability concept into construction industry practice. The literature review identified the mostly used Sustainable Construction (SC) principles and revealed that Most of identified SC practices were influenced by the labour performance. This research is conducted with a quantitative approach using a questionnaire survey in two phases. Phase I was conducted with construction industry professionals, the sample size was 75, and Phase II was conducted with 50 construction labours. Findings revealed, labour having a significant role in implementing SC successfully. Lack of awareness was identified as the main reason for a negative impact from labour in SC. When integrating sustainable concepts into construction, labour management strategies should be also focused apart from the sustainable building materials and technologies to provide the best outcome for the client or society.

Keywords: *Construction Industry, Environmental Sustainable Construction, Economic Sustainable Construction, Labour Performance, Social Sustainable Construction.*

1. INTRODUCTION

More attention towards the environmental pollution, natural resource depletion and accompanying social problems has raised the significance of implementing and improving Sustainable Development (SD) and Sustainable Construction (SC) throughout the world (Chen et al., 2010). Most of the professionals agreed that sustainability highlights the need to simultaneously balance social, environmental and economic goals (Aarseth et al., 2017). Sustainable performance of Construction is essential in SD because, construction industry is a major resource consumer (Shen et al., 2007), applies a higher demand pressure on world natural resources goals (Djokoto et al., 2014) and responsible for the negative effects towards environment (Marques, et al., 2016). SC can be defined as "the creation and responsible management of a healthy built environment based on the prudent use of resources and ecological principles" (Kibert, 1994). Using SC methodologies, significant improvements can be achieved in terms of use of resources, harmful emissions, life-cycle costs and productivity, and building performance (Hakkinen & Belloni, 2011). Yet, due to construction methods practiced and building material used, it is very difficult to make changes in the construction industry (Adjarko et al., 2016). Mainly, resistances occurred due to the requirement of process change, involving the perception of possible risks and unforeseen costs (Häkkinen & Belloni, 2011).

Even though various technologies and methods were implemented authors have identified the importance of labour in the construction industry. As construction industry is a labour intensive industry, when integrating sustainable concepts into construction, labour management strategies should be also focused apart from the sustainable building materials and technologies (Mohd-Rahim et al., 2016). Labour can be defined as all

*Corresponding Author: E-mail – idkumarasinghe@gmail.com

workforces involve in the process that had to carry out to accomplish and to achieve the goal (Karim et al., 2013). Mostly and, especially in developing countries, construction labour factor is not considered as significant, even largest proportion of total project cost is labour cost (Kazaz et al., 2008). Further to the authors, usually site labours represent up to 40 % of the direct cost in large construction projects. The way construction works are planned, scheduled and controlled depends directly on the performance of labours (Mohd-Rahim et al., 2016). Further, Shen et al. (2007) have identified labour cost as a factor related to economical sustainability in the construction stage of a project.

As construction work planning, scheduling and controlling is depend on the labour, design stage and construction stage is affected by the labour. Sustainability implementation of a construction project is done in the design stage and construction stage. As these stages are influenced by labour, sustainability integration in design and construction is also influenced by labour performance. However, there are no researches carried out to identify the importance of labour in SC. Thus, this research is aimed to investigate the influence of labour factor in integrating sustainability concept into construction industry practice.

Accordingly, this paper first presents the findings of the literature review in relation to SC and construction labour involvement in SC. Next, the research method followed by discussions on the relationship between labour factor and SC through the findings are presented. The final section summarises the conclusions derived from the research findings and present recommendations. Influence of labour towards the majority of SC practices was confirmed and lack of awareness was identified as the major reason for low involvement of labour in SC practices. Importance of considering and improving labour performance to SC was recommended through this research.

2. LITERATURE REVIEW

The literature review identified the basics of SC, current application, aspects of SC and importance of labour factor to SC.

2.1. SUSTAINABILITY CONCEPT AND CONSTRUCTION INDUSTRY

While achieving today's social requirements, it is essential to provide favourable environmental conditions to future generations through considering activities of today (Beiriz & Haddad, 2011). According to Voinov (as cited in Aarseth et al., 2017) definitions of sustainability, consider the relationship between human and resources used by the human. Brundtland Report (as cited in Pitt, et al., 2009) defined SD as "meeting the needs of the present without compromising the ability of the future generations to meet their own needs".

Researchers have identified the importance of major three areas in sustainability. The proper interrelationships among society, the environment, and economy are essential to the sustainability (Hutchins & Sutherland, 2008). Among many definitions of sustainability, the need to simultaneously balance social, environmental and economic goals is highlighted by the most of experts in the field (Aarseth et al., 2017). Further, Hutchins and Sutherland (2008) have identified sustainability as the "interdependence of ecological, social, and economic systems", which is known as three pillars of sustainability. According to Construction Industry Research Information Association (CIRIA) (as cited in Pitt et al., 2009), achieving the right balance between these factors supports true sustainability. Therefore, the key areas of sustainability can be identified as environment, economy and social. Yolmaz and Bakou (2015) have identified the area to be covered in these three pillars of sustainability. According to authors, environmental sustainability is about passing the available resources to future. In doing so, considerations on ecological balance and unrenewable resources are essential. Further to the authors, production and consumption balance is controlled under economic sustainability and social sustainability is focused on the rights and freedom of the human.

Today's world, it has become a major necessity to achieve sustainable goals in all sectors of society (Zhang et al., 2011). Because of the significant and direct influence on the environment, economy, and society, the construction industry has become a main sector under SD (Farzanehrafat et al., 2015). The construction industry is considered as the one of the major consumer of non-renewable resources, an extensive source of waste (Wallbaum & Buerkin, 2003) and has a considerable social and economic effect with its ability to provide employment opportunities (Marques et al., 2016).

SC has been defined by many researchers with relation to the SD. SC is an approach to attain SD goals of the construction industry while considering environmental, socioeconomic and cultural issues (Shafii et al., 2006). The aim of SC is to minimise the negative influence to the natural environment (Airaksinen & Matilainen, 2011) and support to save the resources and protect the environment (Zhang et al., 2011). SC effectively involve in social cohesion and job creation, promotion of cultural tourism and regional economic development (Shafii et al., 2006).

2.2. *INTEGRATING SUSTAINABILITY INTO CONSTRUCTION INDUSTRY*

Sustainability practices can be achieved through combining sustainability in project using varies technical solutions, systems and regular practices (Aarseth et al., 2017). Finding environmentally and economically sound design and development techniques for buildings and infrastructure is important to constructions to be sustainable (Shafii et al., 2006). To achieve SC goals properly, various construction activities should be considered and analysed (Ensassi & Mayer, 2005). When implementing SC also, three pillars of sustainability are included. Table 1 shows the critical practices, which should be executed to achieve SC performances.

Table 1: Aspects Covered in Three Pillars of SC

Environmental SC	Economic SC	Social SC
Minimisation of resources consumption [1]	Value for money [8]	Safety and welfare of workers [5]
Reduction of waste [1][2][3][4]	Maximum output with minimum input [8]	Labour relations [5]
Maximisation of resources reuse [1]	Financial affordability [10]	Conflict management among stakeholders [6]
Use of renewable and recycled resources [1][4]	Employment creation [10]	Minimising neighbourhood disturbance [6]
Pollution prevention [1]	Improve competitiveness [10]	Health and safety in construction [5] [7]
Avoidance of environmental health problems [1]		Using local resources [6]
Improvement of indoor air quality [1]		Job satisfaction achievement [6]
Protecting your building materials [3]		Education and training /apprenticeships opportunities [7]
Sorting and disposal of waste [3]		
Planning your building supplies [3]		
Managing inefficient water use [4]		
Avoiding air pollution [4]		
Energy use [2][4]		

Sources: [1] Adjarko et al. (2016), [2] Shafii et al. (2006), [3] Building Research Establishment (2008), [4] Ensassi & Mayer (2005), [5] Talukhaba et al. (2005), [6] Farzanehrafat et al. (2015), [7] Akotia (2014), [8] Zhou and Lowe (2003), [9] Hill and Powen (as cited in Enshassi et al., 2016).

There are different aspects needs to be covered in SC. Further, the involvement of all participants in the construction projects is essential to make the SC implementation success.

2.3. *INFLUENCE OF LABOUR IN INTEGRATING SUSTAINABILITY INTO CONSTRUCTION PRACTICE*

As construction industry is a labour intensive industry, the performance of the people in the industry has a massive influence on the performance of the construction firms (Lill, 2008). Therefore, labour is a key factor to complete construction projects in a more successful manner (Mohd-Rahim, et al., 2016).

Hence, SC should not be only focused on the sustainable building technologies and construction material, but also labour management strategies (Lill, 2008). A sustainable design only can be implemented, if the workers engaging in the construction are properly aware of the sustainable practices and the awareness on sustainability can be given through the training for workers (Kakkar, 2014). According to Mohd-Rahim et al., (2016), even labour shortage has become a crucial risk for achieving sustainability in construction projects. Shen et al.,

(2007) have identified the factors affecting sustainability throughout the project life cycle and labour cost and employment are identified as a significant factor in project construction stage.

Similarly, when implementing SC, labour factor is with a high gravity, which should be carefully considered. Hence, in here the influence of labour factor to SC is described under three pillars of sustainability.

When considering the environmental SC, minimisation resource consumption, waste reduction, water efficiency were mainly identified as practices that affected by labour factor. Kibert (1994) has identified minimisation of resource consumption as the main requirement of SC. Workers' knowledge of the efficiency of handling natural resources is essential for the success of building sustainable buildings (Kakkar, 2014). Preventing and reducing the generation of waste are the most effective way of decreasing the environmental impact of construction waste (Esin & Cosgun, 2007). Teo et al. (as cited in Begum et al., 2009) mentioned there is a significant impact on waste levels from the behaviour of labour in construction because construction is a labour intensive industry. Further, according to Lingard et al., 2001 (as cited in Begum, et al., 2009) motivational influences on the behaviour of construction workers have an important influence on the extent that waste can be reduced.

When considering about the economic SC cost efficiency, construction cost, construction period (Attar et al., 2012), life cycle cost of construction and employment creation (Hill & Bowen, 1997) were identified as aspects that affected by labour. Cost efficiency is about minimising the project cost, life-cycle cost of construction and providing consumer's requirements at a satisfactory level (Akadiri et al., 2012). According to Akadiri, et al. (2012), when sustainability is applied to construction practice, efficiency is promoted and the cost will be reduced through ensuring availability of skills required and labour supply. Poor productivity of construction workers is one of the causes of cost and time overruns in construction projects (Attar et al., 2012). As per Yusof and Misnan, (cited in Mohd-Rahim, et al., 2016), the construction industry is influenced by the availability of skilled and productive labours as the construction industry is a labour intensive industry. Employment creation is a major point for labour-intensive construction industry (Hill & Bowen, 1997).

Importance of labour in social SC was identified under safety, health, and welfare of workers, labour relations and providing training. Nwokoro and Onukwube (as cited in Akotia, 2014) have mentioned that in promoting good health, satisfactory safety practices and certifying the right working environment, which is as well essential in attaining successful social sustainability. According to Attar et al. (2012), labour performances are mostly affected by the health and safety factors. Health and Safety in construction important to SC (Shaffi et al., 2006). Labour performances are affected by the quality of site management and supervision (Kazaz & Acıkara, 2015). Further, Ghate and Minde (2016) have also mentioned labour supervision as a top factor affecting labour productivity. In order to that, according to Delmas and Pekovic (2012), interpersonal contact in a construction site is affecting to the job satisfaction and motivation and it will result in productivity increases. Further, to that, Ghate and Minde (2016) have identified training as another significant factor affecting the labour productivity.

When considering the available literature, a significant relationship between labour and SC could be identified. However, at the moment in SC implementation labour has not been identified as an important factor. Therefore, when rethinking design, constructions, and operations with a sustainable perspective, labour factor is also needed to be considered.

3. RESEARCH METHODOLOGY

According to Kerlinger (as cited in Kumar, 2011) research design is the plan, structure, and strategy that would be used to find the answers to research questions or problems. The research was done with the quantitative approach. The quantitative approach is used in evaluating relationships between two facts compared to the available theories or the findings of any previous research (Creswell, 1994; Fellows & Liu, 2015). As this research is about identifying the relationship between labours and SC, a quantitative approach was used for the in conducting the research.

The design of this research includes; a literature survey, a questionnaire survey in two (02) phases, data analysis and providing recommendations. Data collection was done using questionnaire survey in two (02) phases with construction industry professionals and construction labours. The questionnaires were prepared based on identified factors through the literature synthesis. A sample of the first phase of data collection consists of 75 various professionals in the industry who are involved in labour manging at construction projects with 55%

response rate. Second phase sample is 50 labours and it has 100% response rate due to manual data collection. Data from both phases were analysed using statistical methods. Details of two samples were indicated in Figures 1 and 2.

"Percentage sum of the factor" was the used statistical methods for analysis. MS Excel software application is used for the data analysis. "Percentage sum of a factor" was calculated according to Eq. (01) and Eq. (02). Eq. (01) was used for the construction industry professionals' questionnaire analysis and Eq. (02) was used for the construction labour questionnaire analysis. In calculation was used to analyse the perception of respondents regarding the considered factors. As perception cannot be quantified, total agreeing percentage and disagreeing percentage were calculated without giving weightage to variables. Then, factors were ordered according to the percentage agreed to the argument.

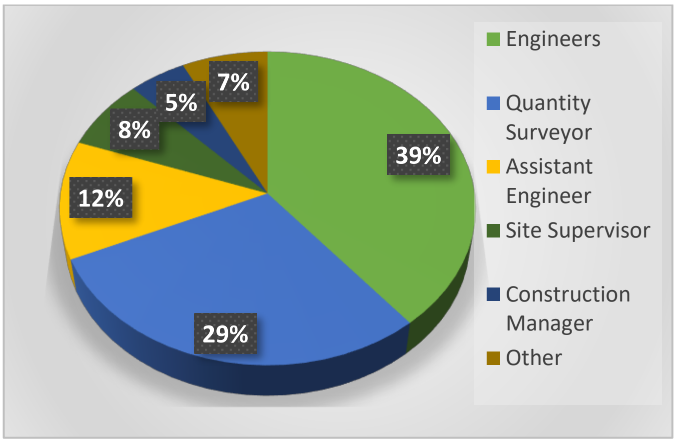

Figure 1: Sample of Phase 02

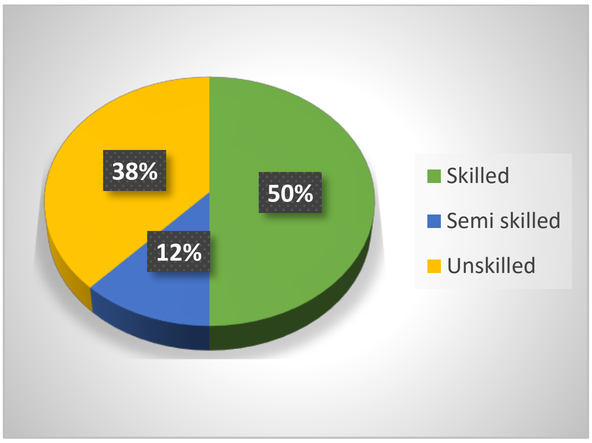

Figure 2: Sample of Phase 01

The equations used in the calculations are as below.

$$\text{Percentage sum of factor (Phase 01)} = R_1 + R_2 - R_3 - R_4 - R_5 \qquad \text{Eq. (01)}$$

Where,

R_1 = Responses percentage for "Very Often"

R_2 = Responses percentage for "Often"

R_3 = Responses percentage for "Rarely"

R_4 = Responses percentage for "Very rarely"

R_5 = Responses percentage for "Never"

$$\text{Percentage sum of factor (Phase 02)} = P_1 + P_2 - P_3 \qquad \text{Eq. (02)}$$

Where,

P1 = Responses percentage for "Yes"

P2 = Responses percentage for "Somewhat"

P3 = Responses percentage for "No"

Through the analysis, most important labour related factors influencing the SC were identified and recommendations were provided to improve the SC aspects.

4. RESEARCH FINDINGS AND DISCUSSIONS

Under the professional survey, findings reveal the current application of SC as very low and the application is also not up to satisfactory level. Lack of government regulations to promote SC and lack of government support have negatively affected on SC implementation. Most of the professionals in the construction industry are knowledgeable about the SC. Therefore, there should be a negative contribution from other stakeholders in the industry hindering SC implementation. Hence, industry professionals should use their knowledge to implement SC and other stakeholders in the construction industry should actively involve in these activities.

Findings regarding labour influence on SC can be discussed in three sections as; environmental SC practices, social SC practices, and economic SC practices. Table 2 includes the results of Phase I of the research. Identified SC practices have been ranked according to the agreed percentage to the argument in Table 2. Results of Phase II of research are summarised in Table 3. It shows the ranking of identified SC practices according to the labours' responses. There are some differences could be identified between results of Phase I and Phase II.

When considering the environmental SC practices under professional survey, labours' lack of awareness regarding environmental impact of construction, labours do not sort out the waste when disposing, high energy wastage due to labour activities, labours' less involvement in reducing energy consumption, labours' less involvement in minimising resource consumption, labours' less involvement in minimising waste generation at construction site are identified as top factors that affecting SC. Poor handling of the material, lack of construction knowledge unproductive and idle labour were identified as main three causes of waste generation.

Table 2: Summary of Percentage Sum of Factors under Phase I

Summary of Percentage Sum of Factors under phase 01- Professional survey		
SC Practice	**Percentage sum of factor**	**Rank**
Labour related environmental practices of SC		
Labours are not aware about environment impact of construction	90.25%	1
Labours do not sort out the waste when disposing	90.24%	2
Energy wastage due to labour activities is high	75.61%	3
Labours do not try to reduce energy consumption at accommodation	75.61%	4
Labours do not try to reduce energy consumption while working	75.60%	5
Labours do not try to minimise resource consumption at site	65.86%	6
Labours do not try to minimise waste generation at construction site	65.86%	7
Labours are not using water efficiency	60.98%	8
Labours are a reason for waste generation at construction site	56.09%.	9
Labours do not try to protect building materials while working and storing	53.66%	10
There is a water wastage occurred due to labour activities	51.22%	11
Labour related economic practices of SC		
There is a high cost impact of poor labour performance to cost of construction	85.37%	1
There is a time impact of poor labour performance to time of completion	85.37%	2
Labour performance is affected to life cycle cost of construction	75.61%	3
Labours do not contribute to get maximum output from minimum input	60.98%	4
Labour related social practices of SC		
Labour performance has influenced by treating all employees in same manner	56.10%	1
Labour efficiency has increased due to safety facilities	41.46%	2
Providing local employment opportunities has affected to labour performance	36.59%.	3
Labours are not provided with training and education opportunities	31.71%	4

Yet, some different results were obtained through Phase II. "Awareness of the importance of minimising resource consumption" and "awareness of the importance of reducing waste generation in construction" got positive responses showing most of the labours have some knowledge regarding the importance of them. Further, "labour practices in minimising resource consumption at the site" and "labour involvement in minimising waste generation at construction site" has got very low values comparing to the awareness. This difference shows that labours knowledge is not enough to implement the practices in site. "Sorting out waste when disposing of" is a top factor. Similar to the professional survey findings, labours also accepted that it is the least involved activity by labours. Further, there is a big difference between "percentage sum of the factor" under two surveys for factors such as "labours try to reduce energy consumption", "labours try to minimise resource consumption", "labours try to minimise waste generation", "labours are using water efficiency". It explained that even labours are doing these practices they are not up to the expected level. It shows that there is a need to be improved.

Lack of awareness can be considered as a main reason for the low involvement of labour in these activities. Further, even labours have knowledge regarding some areas, it is not practically applied. Therefore, there is a need to improve the awareness of labours. Hence, there is a gap between expectation and behaviour of the labours in some SC principles.

Table 3: Summary of Percentage Sum of Factors under Phase II

Summary of Percentage Sum of Factors under phase 02- Labour survey		
SC Practice	**Percentage sum of factor**	**Rank**
Environmental SC practices		
Labours are aware about importance of minimizing resource consumption	88.00%	1
Labours are aware about importance of reducing waste generation in construction	88.00%	2
Labours do not sort out the waste when disposing	44.00%	3
Labours are using water efficiency	32.00%	4
Labours try to protect building materials while working and storing	28.00%	5
Labours are involving in minimizing resource consumption at site	12.00%	6
Labours try to minimise waste generation at construction site	12.00%	7
Labours are reducing energy consumption while working	0.00%	8
Economic SC practices		
Adequate job opportunities are available to labours	88.0%.	1
Social SC practices		
Labours are following the safety instructions and using safety equipment	100.0%.	1
There are health care facilities at site	100.00%	2
Labours are satisfied with the safety facilities at the site	72.00%	3
Labours are not provided with training and education opportunities	72.00%	4
Labours are satisfied with the welfare facilities at the site	48.00%	5
There is no better relationship between labours and management	16.00%	6
Labours are not satisfied with their job	8.00%	7

Then economic SC practices were also analysed. Most critical economic sustainability-related factors affected by labour performances are the cost of construction and time for completion and life cycle cost of construction. Therefore, improving labour performance is important to the contractor to complete projects successfully. Labours' contribution to get maximum output from the minimum input is considerably low. According to labours, there are adequate job labours have adequate job opportunities in the construction industry. When considering the cost of construction, wastage and not protecting material are reasons to increase the cost. Therefore, achieving environmental goals of SC will be a support to achieve economic goals of SC.

According to the findings most critical social factor affecting labour performance is "treating all employees in the same manner". Therefore, it is important to treat all employees in the same manner. The relationship between management and labour has an important role in it. Management staff has a responsibility for maintaining that relationship. Further, labour performance has increased due to providing safety facilities and safety facilities and equipment are available to use of labours. According to results of both phases labours are not provided with training which highly effective on the labour performances.

Therefore, when considering all SC principles, environmental and economic principles of SC are affected by labour performances, while social principles of SC are affecting to the improvement of labour performances. According to the findings following suggestions could be provided to the better integration of sustainable concepts into the construction. Suggestions are mainly focused on the construction industry professionals and should be implemented by construction industry professionals and contracting organisations.

There are areas that awareness of employees should be improved. Awareness programmes should be conducted to increase the labours knowledge regarding these different aspects and importance of those. Areas that are needed to be improved could be identified as sorting out the waste when disposing, reducing energy consumption and reduce energy wastage, minimising resource consumption, minimising waste generation at a construction site, using water efficiency and reduce water wastage and protect building materials. As there is a gap between current labour performance and expectation, guidance and close supervision are essential.

Moreover, labour should be instructed on strategies which can be practically used in minimising resource consumption and waste minimisation.

In conducting awareness programmes, day to day guidance should be improved. Displaying guidance within the construction site is an effective method to transfer messages to labours. Regular seeing will give more impact and motivation to labours.

Rewarding the labours can be used as another method to improve labour performance. It can be done on daily, weekly and monthly basis. Contractors should provide these opportunities to labours. Lack of knowledge of construction methods can be overcome through this. A better relationship is essential to improve labour performances. Therefore, construction site staff should make a better relationship with labours. Staff also should be aware of the importance of relationships and strategies to manage the labours. According to the findings, labour performance has a considerable impact on increasing competitiveness in winning contracts or projects. But there is no method to evaluate the performances of the labours. Therefore, labour performance evaluating method should be implemented. This concludes the recommendations of the research.

5. CONCLUSIONS

This research was aimed to investigate the influence of construction labour factor in integrating sustainability concept into Sri Lankan construction industry practice. Through the literature, it was identified that there is a significant involvement in labour with SC. The argument was confirmed by the research. The study reveals that SC in Sri Lanka is not satisfactorily applied and therefore, there is a need improve the SC in Sri Lanka. As most of the professionals are knowledgeable about SC, the involvement of other personnel in construction was evaluated. When considering the influence of labour, environmental and economic principles of SC are affected by the labour performances, while social principles of SC are affecting to the labour performances. Better labour performances are resulting in achieving environmental and economical sustainable goals. Fulfilling social SC requirements will be helpful to achieve better labour performances. Lack of awareness regarding environmental impact was identified as major cause of improper actions of labour. High energy consumption, wastage of resources, not minimising the resource consumption were identified as major issues relating to environmental requirements of SC. Further to that labour performances are highly affected to the cost of construction, time for completion and life cycle cost of construction. Improving labour performance is essential to achieve cost and time targets of construction. Labour performance could be improved by providing safety equipment and facilities, treating labours in the same manner and through training. In order to that, improving labours' awareness, guidance and close supervision are suggested to improve labour performance. Completing social principles of SC will also improve the labour performance. As discussed in the previous sections of this paper, there is the significant role of labour factor in SC and proper management of labour factor will be more beneficial to achieve SC goals of the construction industry.

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TOOL FOR ASSESSING LEAN MATURITY IN CONSTRUCTION PROJECTS IN SRI LANKA

N. Thilakarathna[1*] and Lalith De Silva[2]

[1]College of Construction, Engineering & Living Science, Otago Polytechnic, New Zealand

[2]Department Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

The Non-Value Adding Activities (NVAAs) generated in a construction process are recognised as one of its major weaknesses since they adversely affect performance and efficiency and produce unwanted cost. Lean construction applies lean production principles to the construction industry to minimise NVAAs in construction projects and maximise the value provided to clients. Lean is an innovative construction management approach which is linked closely to the overall life of a project to ensure its success. It is vital to measure the extent to which lean techniques have been applied in a certain project in order to implement more suitable lean techniques in future projects. This paper presents such a mechanism developed for assessing lean maturity in construction projects in Sri Lanka. A detailed literature review was carried out to identify the examples of NVAAs and to investigate the widely used lean techniques in construction projects. Quantitative research approach was adopted through three different surveys. Both surveys one and two were based on questionnaires and the data was collected from industry professionals. The first survey for project quantity surveyors, site engineers and construction engineers to identify NVAA, and the second survey for project managers in building construction projects to examine the application of lean techniques. The research technique for the third survey was semi-structured interviews for senior managers in top grade building construction companies. The data was then used to map NVAAs against lean techniques and emphasise the most suitable lean techniques in different stages of construction projects. Finally, a tool for assessing lean maturity of a construction project was developed to measure the lean implementation of completed projects in order to improve the application of lean techniques in future construction projects. The tool was thereafter validated through an expert survey and implemented in few recently completed projects.

Keywords:*Assessment Tool; Construction Projects; Lean Implementation; NVAAs.*

1. INTRODUCTION

1.1. RESEARCH PROBLEM

Construction Industry has been suffering with low productivity, insufficient quality, time and cost over runs, poor safety, frequent disputes, lack of innovation, project asking so long and always exceeding the client's budget (Lathem, 1994; Eagan, 1994; Smith et al., 1999; Kagioglou et al., 2000; Salem et al., 2006; Emuze & Smallwood, 2011; Al-Aomar, 2012; Vilashini & Neitzert, 2012). The main reasons are insufficiency and waste with NVAAs within the construction projects not adding any value to the final product. Therefore, the NVVAs incur costs and hinder the performance of the construction projects are required to be minimized. Most construction managers agree that the industry is vulnerable to multiple wastes, overruns, delays, errors, and inefficiencies (Al-Aomar, 2012). Senaratne and Wijesiri (2008) have revealed that a considerable amount of waste lies in the flow processes of construction. The greatest obstacle to waste removal in general is failure to recognize it. This is prevalent in the construction industry because it is not well understood by the construction personnel (Alwi et al., 2002). In summary, the construction sector has a wide range of activities including the

*Corresponding Author: E-mail – nilmini.thilakarathna@op.ac.nz

provision of professional and technical inputs. Activities that do not add value simply result in waste which absorb resources and does not add any value to the final product and therefore these NVAAs need to be eliminated. By eliminating wasteful activities, processes can become 'lean' providing 'more with less' resources (Womack & Jones, 2003). The traditional thinking of most of the construction related organizations is on conversion activities and flow activities and value considerations are ignored. The goal of lean construction is to implement the project while maximizing value, minimizing waste, and pursuing perfection. Hence, the implementation of lean techniques into construction has been identified as one of the best approach to minimize NVVAs in construction projects. However, there is a lack of mechanism to assess the level of implementation of lean techniques in a particular construction project in SLCI and this paper presents a tool for assessing lean maturity of a completed project in order to improve the lean implementation for future projects to minimize the NVAAs and achieving long-term sustainable benefits by becoming lean.

1.2. RESEARCH METHODOLOGY

Firstly, the examples of NVAAs in construction projects were identified through an extant literature synthesis and the existence of these examples in SLCI were surveyed among constructional professional such as engineers, quantity surveyors, construction managers who work in construction projects for more than 5 years' experience in Colombo and suburbs. Findings revealed that all examples of NVAAs are existence at a higher level in SLCI too. Next, the widely used lean techniques developed in manufacturing industry and then applied in lean construction in different other countries were explored through the literature review and the level of implementation of these lean techniques in SLCI was examined via the second survey which was carried among the project managers who has the single point responsibility in building construction projects for more than 10 years. The results revealed that the implementation of lean techniques in SLCI is at a lower level. Thirdly, the examples of NVAAs and Lean techniques were mapped via semi structured interviews conducted for the senior managers of top graded construction companies in SLCI to identify the most suitable lean techniques to minimize NVAAs in SLCI. Furthermore, the most appropriate lean techniques for different stages of construction processes were also identified. Finally, a tool for assessing lean maturity was developed using the data collected from the study and the tool was refined to a software application. The extent of the implementation of lean techniques in a particular construction project is assessed by using this tool and the level of lean maturity of the completed project would assist construction professionals to adopt the implementation of more suitable lean technique in future projects in order to minimize NVAAs in SLCI. The Capability Maturity Model (CMM) conceived by Watts Humphrey, aids in the definition and understanding of an organization's processes. CMM is recommended for describing evolutionary levels of organizations in order to describe the level of value based management that an organization has realized or wants to aim for. Hence, CMM was selected to assess the lean maturity of a construction process as this model provides specific steps and activities to move from one level to the next level. These levels are named as Initial, Repeatable, Defined, Managed and Optimizing. Maturity gained by a construction project through lean implementations could be assessed defining levels of CMM depending on the implementation of particular lean technique. Having described the background of the development of the tool, the next section presents the examples of NVAAs in construction projects.

2. EXAMPLES OF NVVAS

2.1. EXISTENCE OF NVVAS IN CONSTRUCTION PROJECTS

NVAAs have been defined as the activities which does not add any value to the final product are merely a waste (Koskela, 1992). Waste is generally associated with waste of material in the construction process while NVAAs such as delays, transportation of material and others are not recognized as waste. Most of these activities are intangible (Senaratne & Wijesiri, 2008) and invisible. Activities that do not add value are simply wasteful and should be eliminated Taiichi Ohno has identified seven forms of waste that are part of lean manufacturing. In the context of both construction and production, waste is primarily defined under seven categories; defects (errors), delays, over processing, over production, excess inventory, unnecessary transport and conveyance of material and equipment, and unnecessary motions and movement of people (Ohno, 1988). NVAAs are the major cause of schedule delays, cost over runs and other related problems in the construction projects (Emuze & Smallwood, 2011). According to Salem *et al.* (2006), there is considerable waste in the construction projects which goes unnoticed. Previous studies (Senaratne & Wijesiri, 2008; Vilashini *et al.,* 2011; Rahman *et al.,* 2012) disclose that the workforce in the domestic construction industry is ignorant of these NVAAs that create waste and hinder construction performance. According to Koskela (2004), these wastes in the flow processes of construction such as 'non-conformance quality costs' consume 12% of the total project cost, poor material management results in 10-12% of the total labour cost, time used for NVAAs amounts to 2/3 of the total project time and lack of safety measures amounts to 6% of the total project cost. Thus the value hindrance by waste in the flow processes of construction is quite evident and it indicates the necessity to implement a concept such as lean construction. Waste is a major problem in the construction industry and it amounts to 60% of the construction effort (Vilashini *et al.,* 2011). A study focussing on the construction efficiency made by the National Institute of Standards and Technology in the United Kingdom indicates that 25-50% of waste relates to coordinating labour and managing, moving, and installing material. Many researches (Mossman, 2009; Horman & Kenley, 2005; Vilashini *et al.,* 2011) have revealed that a major portion of time in construction is devoted to wasteful activities. Mossman (2009) has stated that 5-10% of the construction effort is for creating value, 30 -35% for supporting value creation and that 55-65% is wasted with much of the activity that supports value creation being logistics. Furthermore, Horman and Kenley (2005) have contended that as much as 49.6% of the construction operative time may be devoted to NVAAs. In addition, NVAAs have been identified as one of the problems negatively impacting on issues relating to variations. Waste that generates in the flow activities is recognized as a major disadvantage, which hinders performance and efficiency of constriction activities. According to Rahman (2012) every system contains waste. A link exists between waste in a project and its cost. Vilashini *et al.* (2011) have disclosed that the analysis of the construction process indicates that construction activities can consist of 55% of NVAUA (Non Value Adding Unnecessary Activities). One third of these activities result from factors under the control of management such as rework and errors. More examples of NVVAs are presented in the next section.

2.2. EXAMPLE OF NVAAS

First, the examples of NVAAs were recognized from extant literature review and then, these NVVAs examples were categorized into seven types of waste introduced by Taichi Ohno. The seven types of wastes are; defects or rework, unnecessary waiting, unnecessary motion, inventory, extra procedures, unnecessary transport and overproduction. In addition to the above classification, an eighth category was identified as ' other' for waste which does not fall into any of the above mentioned seven categories. Forty nine examples of NVAAs in construction projects were identified from the literature review and these examples are illustrated in figure 2.1 below. Among these examples, thirteen number of examples are in the category of defects and nine and seven of them are in waiting and extra procedure categories respectively. Four number of examples are explored from other four categories.

Defects	D01NA01	Repair Work
	D02NA02	Design errors
	D03NA03	Design changes
	D04NA04	Installation errors
	D05NA05	Vendors errors
	D06NA06	Damage by other crafts
	D07NA07	Incomplete Installations
	D08NA08	Rehandling materials
	D09NA09	Damaged Materials on site
	D10NA10	Poor material allocation
	D11NA11	Rework
	D12NA12	Site layout is not carefully planned
	D13NA13	Uncomplete work
Waiting	W01NA14	Delay to schedules
	W02NA15	Waiting for Instructions
	W03NA16	Waiting for equipment repair
	W04NA17	arrive
	W05NA18	Equipment freequently
	W06NA19	Waiting for Clarifications
	W07NA20	Waiting (for people, material)
	W08NA21	Activitiy Delay
	W09NA22	Idle Time
Motion	M01NA23	movement
	M02NA24	Unnecessary motion
	M03NA25	Excessive labour movement
	M04NA26	Excessive material movement
Inventory	I01NA27	Material stocks
	I02NA28	Inventory work
	I03NA29	Excess material inventory
	I04NA30	Inventories
Extra Procedures	E01NA31	Unnecessary processing
	E02NA32	Long approval processes
	E03NA33	Retests
	E04NA34	Excessive safety measures
	E05NA35	Excessive supervision
	E06NA36	Excess information
	E07NA37	Excessive training time
Transport	T01NA38	Unnecessay material
	T02NA39	Travelling time
	T03NA40	Unnecessary Transport
	T04NA41	Long transport time
Overproduction	OV1NA42	Unwanted Productions
	OV2NA43	Unnecessary work
	OV3NA44	Material waste
	OV4NA45	Inefficient work
Others	OT1NA46	specification
	OT2NA47	Taxes
	OT3NA48	Pilferage
	OT4NA49	Making - do

Figure 1: Examples of Non-value Adding Activities

2.3. *NON-VALUE ADDING ACTIVITIES IN SRI LANKAN CONSTRUCTION INDUSTRY*

Data collected from the SLCI through the survey one reveals that almost all examples of NVAAs identified through the literature review have been confirmed by the respondents to the surveys as prevailing in the construction projects. Moreover, the findings showed that NVAAs are generated at a significant level in the construction projects in Sri Lanka. Further it was revealed through the surveys that the most significant categories of NVAAs are 'Defects' and 'Waiting'. It can also be identified that NVAAs occur to an extent of 59% throughout construction projects. Hence, it can be concluded that there is a requirement for minimizing these NVAAs which negatively affect the productivity of construction and its value for money. Data obtained through this survey, was statistically analysed using SPSS software and all NVAAs identified through the literature review were found to be present in the construction projects in Sri Lanka as well. Figure 2.2 illustrates the NVAAs present in the construction projects in Sri Lanka. X axis represents NVAAs while Y axis represents the response rate related to each non-value adding activity. The Figure shows that the minimum level of existence of NVAAs is 35% and that its maximum level is 85%.

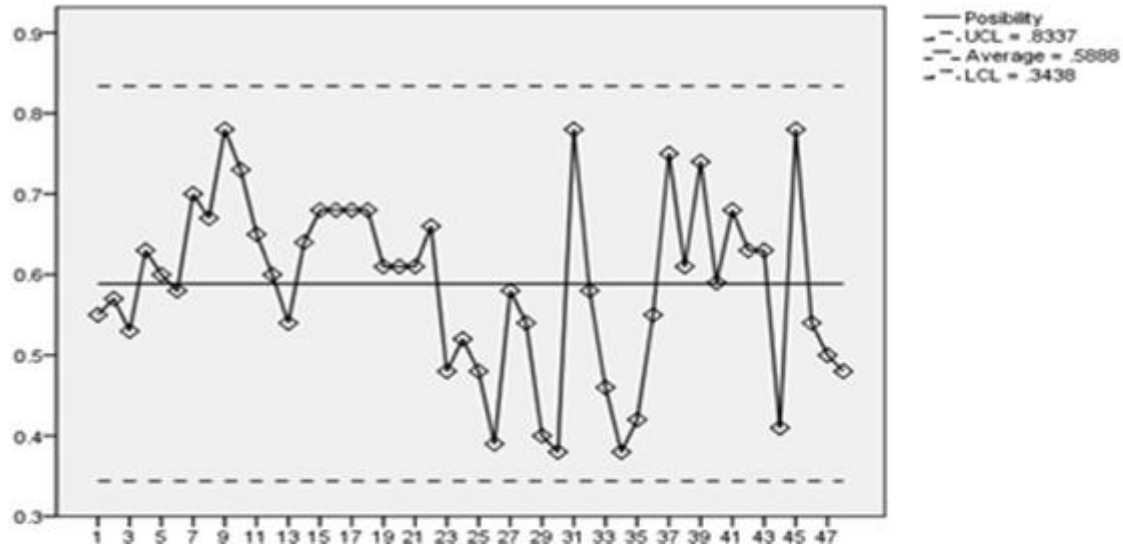


Figure 2: Existence of NVAAs in Construction Projects in Sri Lanka

Findings from Survey one were further analysed to identify the most critical NVAAs in the construction projects in Sri Lanka and each category of waste was considered separately with a view to prioritizing the NVAAs in the construction projects. The most critical examples of NVAAs in construction projects in SLCI is demonstrated in Table 1.

Table 1: The Critical Examples of NVAAs in SLCI

1	Repair Work	9	Waiting for Instructions
2	Design Errors	10	Waiting for Equipment Repair
3	Incomplete Instllations	11	Waiting for People and Materials
4	Rehandling Materials	12	Idle Time
5	Damage Materials on site	13	Excessive Labour Movements
6	Poor Material Allocation	14	Retests
7	Delay to Schedules	15	Excessive Safety Measures
8	Delay to Instructions		

3. LEAN CONSTRUCTION IMPLEMENTATION

3.1. LEAN CONSTRUCTION

Lean construction is a new way to manage construction and this concept is still new to many construction industries in the world. Lean production was developed by Toyota and led by Engineer Ohno who was dedicated to eliminating waste. The term 'lean' was coined by the research team working on international auto production to reflect both the waste reduction feature of the Toyota production system and to contrast it with craft and mass forms of production. The lean philosophy can be considered as a new form of design and production that is different from mass and craft forms of production through the objectives and techniques applied on the shop floor, to design and along supply chains. Koskela (1992) has concluded that eleven important principles some of such as reducing waste, variability, cycle and increasing transparency, are essential to the lean philosophy. Ballard (2008) and Womack and Jones (2003) have refined and expanded the lean concept for construction and have outlined the basic lean thinking principles. The lean concept has proven to be effective in increasing environmental benefits by eliminating waste, preventing pollution and maximizing the owners' value (Huovila et al., 1998; Salem et al., 2005). In addition, lean produces an operational and cultural environment that is highly conducive to the minimization of resource depletion and pollution prevention, and that lean provides an excellent platform for environmental management tools such as life cycle assessment and design for environment. Wu and Low (2011) have revealed that the lean production philosophy which originated from the Toyota production system advocates reducing or eliminating NVAAs at the same time as improving the efficiency of value adding activities.

According to Womack and Jones (2003), the five principles of lean thinking are value, value stream, flow, pull and perfection. LC is defined by fundamental concepts, basic practices and a common vocabulary. Together these create a new paradigm for managing work in projects from their conception to completion. The manufacturing industry has been a constant reference point and a source of innovation for the construction industry over many decades. All construction activities can be divided in to two types, the first being conversion activities which produce tangible results. The second type is flow activities which bind conversion activities together during the delivery process of the output. Although all activities incur cost and consume time, according to lean principles only conversion activities add value and these should therefore be made more efficient, where as non- value adding flow activities should be reduced or eliminated (Koskale, 1992). The lean concept is one strategy adopted by the construction industry from the manufacturing industry to improve its own performance (Vilashini & neitzert, 2012). Lean construction is a new way to manage construction implementing the guidelines of Lean Project Delivery System developed by LCI (Ballard, 2008). Moreover, lean construction, assumes that construction is a kind of production process (Bertelsen, 2004). The widely used lean techniques in construction projects are presented in the next section.

3.2. LEAN TECHNIQUES

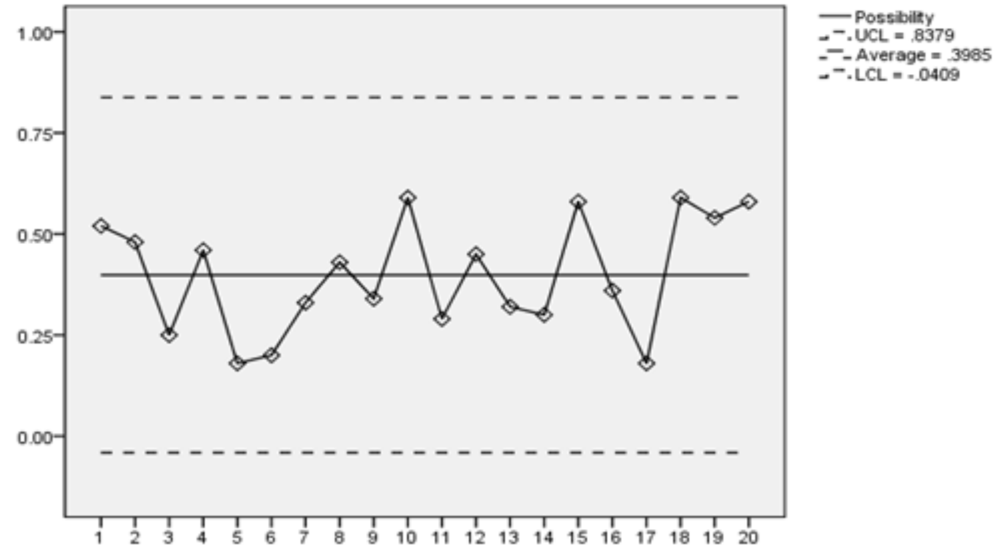
In summary, lean is a systematic method for waste minimization and several techniques have been developed for the manufacturing industry and then these techniques have been applied for the construction industry and reaped benefits. Egan (1994) has revealed that Lean Construction presents a coherent synthesis of the most effective techniques for eliminating waste and delivering significantly sustained improvements. The philosophy of lean is an umbrella that covers a multitude of tools and techniques commonly used within the industry (Salem *et al.,* 2005). After reviewing the lean implementation cases in the extant literature, the widely used lean techniques in the construction processes were identified as illustrated in figure 3. These LTs were numbered as LT01 to LT20 for easy reference.

LT01	Last Planner System	Planning and control system implemented on construction projects
LT02	Just in Time	Stock of Materials are kept to the bare minimum
LT03	3D Modelling	Computerized 3D design system
LT04	Visualization	Visualization through posting various signs and labels
LT05	Building Information Modelling	Creating a shared knowledge resource for information
LT06	Value Stream Mapping	Maps are prepared at the project level and then decomposed to better understand
LT07	Reverse Phase Scheduling	A schedule that works backwards from the completion date
LT08	Off Site Manufacturing	Manufacturing and assembling process
LT09	Kaizen	Continuous improvement “good change"
LT10	Five S	Approach to housekeeping within Lean
LT11	Poka-yoke	Generation of ideas that alert for potential defects
LT12	Target Value Design	Method that assures customers get what they need.
LT13	First Run Studies	Use video files, photos, or graphics to show the process
LT14	Relational Contracting	Contracts as relations rather than as discrete transactions
LT15	Target Costing	Improve a company’s efficiency and effectiveness in cutting costs
LT16	Set based Design	Design alternatives up-front to allow for trade-offs
LT17	Kanban	One-way to do this is to smooth and balance material flows
LT18	Total Quality Management	A combination of quality and management tools and reducing losses
LT19	Work Standardization	Documenting the current best practice
LT20	Work Structuring	Work flow more reliable and quick while delivering value to the customer

Figure 3: Widely Used Lean Techniques in construction projects

3.3. LEAN CONSTRUCTION IMPLEMENTATION

Rahman (2012) has stated that the emerging concept of LC is concerned with the application of lean thinking to the construction industry. During the past ten years, there has been a growing interest in the LC among academics all over the world. These researchers seek to investigate the extent to which the Japanese model of lean production can be applied to the construction industry. From the study of its background, LC appears to have resulted from the adaptation and implementation of the Japanese manufacturing principles in construction practices. LC, assumes that construction is a kind of production process (Bertelsen, 2004). Lean project management is focused on implementing the guidelines of Lean Project Delivery System which includes Lean Project Definition, Lean Design, Lean Supply and Lean Assembly. The Lean Design phase transforms the conceptual design of the project into a lean product and processes the design to be consistent with project scope and design criteria. The lean supply module consists of the detailed engineering of the product design, the fabrication or purchasing of components and material, and the logistics of deliveries and inventories. The Lean Assembly ranges from the delivery of tools, material, and components to commissioning and project delivery to the client (Al-Aomar, 2012). LC keeps an eye on the value added element of the construction process (conversion) as well as the non-value added elements (flow, delay, and errors). A lean delivery emphasizes a cost effective and on-time handover with no delays or rejects or quality issues. According to Salvatierra-Garrido and Pasquire (2011), LC experience commonly connects construction practices with the Transformation-Flow-Value model of Koskela, where value is mainly delivered during the production process at site. Consequently most of the efforts have been made to satisfy the requirements of the paying client. Bertelsen (2004) has argued that the clients represent interests from three main groups; owner, user and the society who value different things at different times through the life cycle of construction projects. Other countries such as United Kingdom, United States of America, and Singapore have reaped sustainable benefits through proper implementation of lean construction. Extant literature offers several case studies on such lean construction implementations. Overall, there is sufficient evidence on the implementation of lean techniques in construction (Thilakarathna & Senaratne, 2012). However, some are being implemented without any awareness on ‘lean philosophy’ and only as a requirement for a quality assurance procedure. Hence, it is important that construction companies rethink about implementing lean techniques consciously to reap the real benefits of lean applications by avoiding general construction issues. Data collected from Survey for this study revealed that the level of implementation is at a lower level. Further it is revealed that almost all lean techniques are implemented in the construction industry in Sri Lanka at different levels and that none of them was at zero level. All most all 20 lean techniques are being implemented at different levels in the construction industry in Sri Lanka and their average level of implementation is reported to be 40% which is a considerably low figure. Therefore, the construction industry in Sri Lanka is significantly lagging behind in implementing lean techniques in their construction projects (Thilakarathna & De Silva, 2014) and therefore there is substantial scope to improve the implementation of lean techniques in Sri Lanka. Figure 4 indicates the level of implementation of the 20 lean techniques selected along with the number of responses received to illustrate the implementation of lean techniques. The Y axis of the graph shows the cumulative count of the responses received for each of the lean techniques selected for the study. Five S, Total Quality Management, Target Costing, Work Structuring, Work Standardization and Last Planner are techniques that are being implemented at a higher level whereas BIM, kanban, Value stream mapping and 3D modelling are implemented at lower levels.



Lean techniques

Figure 4: Current Level of Implementing Lean Techniques in The Construction Industry in Sri Lanka

3.4. *MAPPING NVAAS WITH LEAN TECHNIQUES*

The research findings of the existence of the examples of NVAAs and the level of implementation of LTs in SLCI were presented in the above sections. Next, it is vital to present which LT is most suitable to minimize NVAAs in different stages of construction. Hence, this section discusses the mapping of most critical 15 number of NVAAS with LTs to identify the appropriate LT implementation for construction projects. The third survey based on semi-structured interviews were conducted among twenty number of senior managers of top graded construction companies in order to map NVAAs and LTs. A guideline was designed to map NVAAs against lean techniques and was given to the interviewees to mark their responses a separate description for each lean technique was provided. The data revealed that there is no direct one to one relationship between a particular NVVA and LT. It is a many-to-many relationship which shows a strong relationship among NVAAs and LTs. Therefore it is identified that by implementing LTs, NVAAs can be minimized. It can also be concluded that to minimize each NVVA, several LTs can be utilized. It can therefore be confirmed that (i) to minimize one NVVA several LTs can be utilized and (ii) in utilizing a particular LT, several NVAAs can be minimized. Hence, these findings reveal that there is a strong relationship between LTs and NVAAs. The results of the survey were further analysed and LTs were categorised into 4 groups based on the stage of their implementation, i.e varying from the initial stage of a construction project to its completion align with lean project delivery from lean definition to lean assembly.

The entire life of a construction project can be divided mainly in to five stages (RIBA Plan of work) and the first four of these stages were considered for this study since the last stage comes in only after reaping the benefits of implementation of lean principles. Table 2 illustrates the implementation of the LTs selected for this study in the four different stages of a construction project delivery system. The figure shows that most of LTs can be applied in the Design, Pre-construction and construction stages of a project. Lean techniques such as Five S, Target value design and Target costing can be implemented from the Preparation stage itself. Set based design technique, LT16, works with design alternatives was identified as not suitable with many alternatives. These data were further analysed and used to develop a tool to measure up to which extent the lean techniques are applied in each stage of a construction project in order to establish the Lean Maturity of that project. If the Project is matured enough with lean implementation, NVAAs are kept minimized and project would gain more benefits with a waste reduction nature.

Table 2: Proposed Lean Techniques Implementation

Lean Techniques		Lean Project Delivery			
		Preparation	Design	Pre-constructio	Construction
LT01	LPS				√
LT02	JIT			√	√
LT03	3DM		√	√	√
LT04	VIS		√	√	√
LT05	BIM		√	√	√
LT06	VSM			√	√
LT07	RPS		√	√	√
LT08	OSM		√	√	√
LT09	KAI		√	√	√
LT10	5S	√	√	√	√
LT11	PY		√	√	√
LT12	TVD	√	√		
LT13	FRS			√	√
LT14	RC		√	√	√
LT15	TC	√	√	√	√
LT17	KNB				√
LT18	TQM		√	√	√
LT19	WSD		√	√	√
LT20	WST		√	√	√

4. A TOOL FOR ASSESSING LEAN MATURITY

4.1. DEVELOPMENT OF THE TOOL

The purpose of this tool is to measure the extent of application of lean techniques in different stages of construction projects and then assess the lean maturity of that particular project. Twenty lean techniques were identified through the literature review and confirmed through the surveys carried out in Sri Lankan construction industry. Moreover, it was revealed that these lean techniques are being implemented at a low level. Further it was revealed that one of the techniques listed among the twenty number of techniques is not appropriate to minimize non value adding activities and that the remaining nineteen techniques can be implemented in construction projects. Therefore, the proposed tool was designed using only these 19 lean technique. Hence, the construction projects were categorized in to four main stages (RIBA plan of work) and the stages were characterised for this study as (i) Preparation stage (Lean Definition), (ii) Design stage (Lean Design), (iii) Pre-construction stage (Lean Supply), and (iv) Construction stage (Lean Assembly) for ease reference to the construction professionals whom may be new to lean project delivery. The weighted average of each lean technique was calculated using the data obtained through Survey and through interviews. It was revealed from the survey that certain lean techniques can be applied in several stages. The weighted average calculated for each lean technique was then distributed among the weighted average allocated for each lean technique in each stage of a construction project. The next step of the data analysis was to calculate the weighted averages of all nineteen lean techniques based on the data collected. The above results reveal that there is a relationship between lean techniques and NVAAs. LT01, LT 02, LT04, LT10, LT18 and LT19 show a strong relationship with a strong weightage when implementing them to minimize NVAAs whereas LT14 with a weighted average of 0.008 and LT17 with a weighted average of 0.016 show a relationship which is less strong when compared with the rest of the lean techniques whose weighted averages range from 0.04 to 0.065. The Capability Maturity Model (CMM) was selected to assess the lean maturity of a construction process. The scoring system was defined as 1, 2, 3, 4 and 5 for each level, 5 is the maximum or the Optimizing level whereas 1 is for lowest level, the Initial level which needs to be developed. Figure 5 shows the appearance of the tool. The first column indicates the stage of construction whereas the second column refers the LT numbering in each stage. For example, first stage, there are three number of LTs to implement. Next column briefly states the description of each LT and Results are indicated against each LT in each stage.

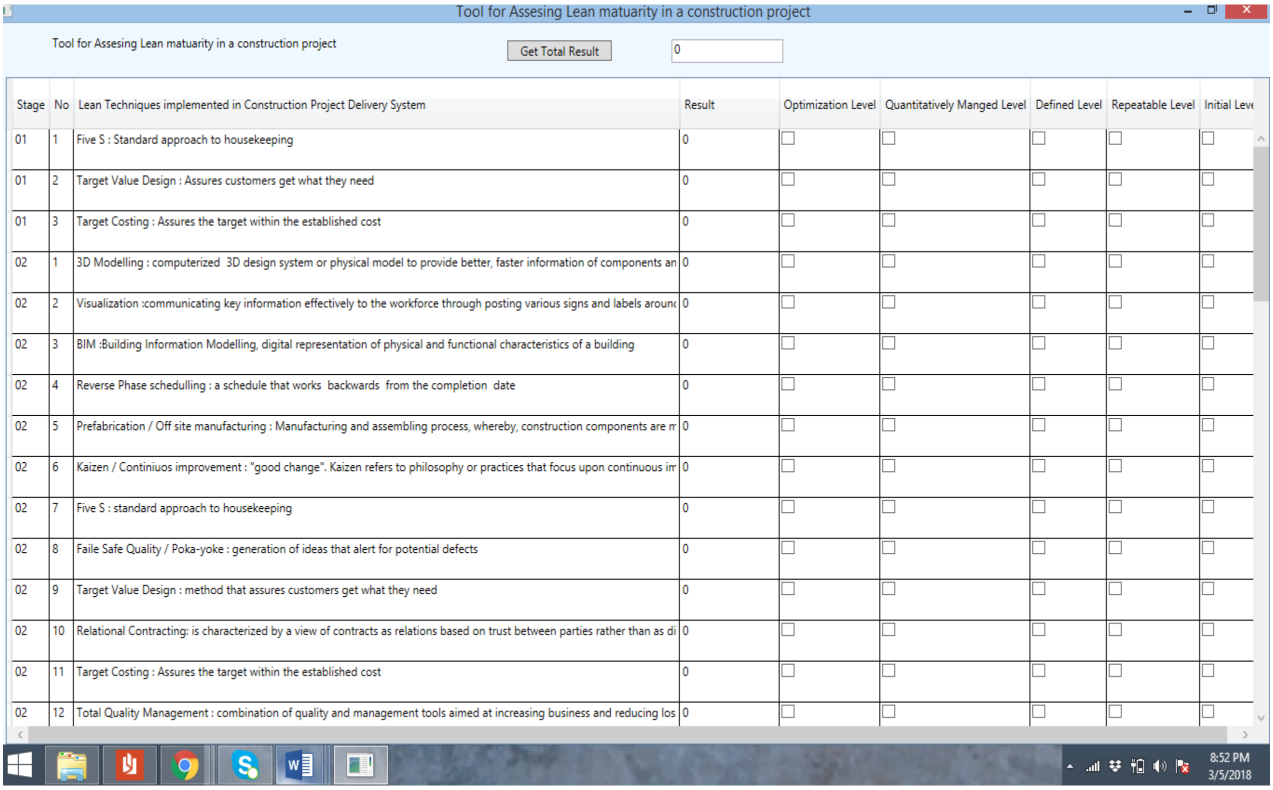


Figure 5: Appearance of the Tool for Assessing Lean Maturity

4.2. *USE OF THE TOOL AND ITS OPERATION*

The aforementioned tool was further developed to a user friendly software application. The outline of the interface of the tool consists of 19 Lean Techniques into four different stages of construction with a brief description to each techniques against CMM levels with definitions. Each stage of CMM was given a score and the weighted average of each lean technique of each stage of a construction project delivery system was specified in the tool. The user may select the lean technique used in each stage by deciding up to which level it is applied in that particular stage, and the program will produce the scores and display the total score at the end of the exercise. In one construction project, the maximum score displayed was 5 and the minimum 1. Select the construction project which lean maturity to be assessed open the interface of the software with an aid of a suitable electronic device. User may select each lean technique and appropriate level of implementation will be selected his or her knowledge in construction project practice. A brief introduction to each tool is available on the application and it is user friendly with developing a software considering events, objects and behaviour to judge the implementation of each lean technique. The data obtained using the tool was from five construction projects which were all in the stages of being completed. The data in Table 3 shows that these projects are not well matured in lean and that there may be hindrances to their performance which would have made them inefficient. When comparing the scores of the projects, project 5 is the most matured project in lean where project 3 is the least matured project in lean. Therefore, results of the application of tool reveal that further lean implementation is required for future projects in order to become more ‘lean’ with less NVAAs to solve the productivity issues in construction projects.

Table 3: Lean Maturity of Five Construction Projects

Final Scores after application of the tool		
1	Proposed housing scheme at Athurigiria	2.55
2	Proposed office building at Colombo 08	2.76
3	Proposed apartment complex at Battaramulla	1.78
4	Proposed apartment complex at Rajagiriya	2.95
5	Proposed mix developmet for offices, shops and apartments at colombo 08	3.05

5. CONCLUSIONS AND WAY FORWARD

Inefficiency and waste in construction projects are the main factors that adversely affect the performance of construction activities and NVAAs have been identified as the main cause for this inefficiency and waste. Hence the research problem of this study was the existence of NVAAs in construction projects which have to be minimized if performance is to be improved. The research approach selected to solve this problem was lean implementation. The literature indicates that 'lean' minimizes waste and that lean techniques can be applied to minimize NVAAs in the construction projects. Lean is an innovative construction management approach which is linked closely to the overall life of a project ensuring its success. The background to this study indicates that the significance of developing a mechanism of assessing lean implementation in SLCI in order to implement more lean techniques in future projects. Hence, the aim of this research was to develop a tool for assessing lean maturity of construction projects in SLCI for the implementation of lean techniques so that NVAAs in construction projects could be minimized. The study commenced with a preliminary literature review to identify the basic details of lean implementation and a detailed literature review was carried out to identify the research problem which was the existence of NVAAs in construction projects with examples. The research approach was the implementation of lean techniques that will solve the problem. Several lean techniques which can be implemented in different stages of construction projects were further identified. The quantitative research approach was adopted to collect the data from Sri Lankan construction industry and findings revealed that NVAAs are existence at a higher level in the construction projects and lean implementation is at a lower level. Moreover, examples of NVVAs and the most suitable lean techniques was mapped to identify which LT is most appropriate for each stage of construction. Finally, a tool was developed as a software application and then this tool was applied to five construction projects to make an assessment of their lean maturity. Finally, expert opinions were used to refine the tool that had been developed based on the main findings of the research.

This study was further continued to develop a framework for lean implementation as the last objectives of the study and developed framework would be further refined through expert opinion. The primary goal of this framework is to guide professionals who render their services to clients, contracting organizations, consultants and developers in the construction industry on how to improve the efficiency of construction activities by implementing lean techniques. This will further assist them to identify guidelines to implement lean techniques and the benefits of implementing lean techniques. Further this framework will identify the challenges that exist for implementing lean techniques and the suggestions to overcome these challenges Moreover, this research could be extended by engaging larger samples to see whether new findings other than the findings already revealed through literature review could be made, especially with regard to the challenges of implementing lean techniques. The application of the tool could also be extended to more cases to reinforce the conclusions made. It will be interesting to know whether new cases would produce the results already obtained through this research study which would strengthen the generalizability of this research.

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TOWARDS DIGITAL DELIVERY OF METRO-RAIL PROJECTS IN INDIA

Madhumitha Senthilvel[1], Ranjith K. Soman[2], Ashwin Mahalingam[1*], Jennifer Whyte[2], Benny Raphael[1], Ioannis Brilakis[3] and Koshy Varghese[1]

[1]Indian Institute of Technology Madras, India

[2]Imperial College London, United Kingdom

[3]University of Cambridge, United Kingdom

ABSTRACT

There is a large programme of metro-rail construction in India, upgrading public transportation systems to provide rapid transit to millions of people in major Indian cities. The scale of this development makes it important to innovate as improvements in design, construction and operations can have a significant impact on built asset sustainability. As integrated digital delivery approaches are becoming used internationally in infrastructure projects, new questions arise about their application and suitability in these Indian metro-rail projects. This paper is based on a research collaboration involving desk-based study, site visits, and a hosted workshop with 40 participants including client representatives of six major Indian metro-rail projects along with technology providers and delivery teams. Findings are that - while Nagpur Metro project is most advanced in implemented Building Information Modelling (BIM) in its planning and design phase, translating practices from Crossrail in London into the Indian context - there are significant challenges in adopting digital practices in the delivery of new transportation schemes in Indian cities. These challenges include stakeholder awareness and education; integration and interoperability; standardization; cost implications and BIM strategy. The paper concludes with some potential directions for future research and discusses the potential for India to 'leapfrog' a generation of technology to implement low-cost effective digital solutions.

Keywords:*Digitisation; Infrastructure; Innovation; Metro-rail Projects.*

1. INTRODUCTION

There is a large programme of metro-rail construction in India, upgrading public transportation systems to provide rapid transit to millions of people in major Indian cities. At present, India is experiencing a sustained period of rapid economic growth nearing 9% per year between 2003/04 and 2010/11 (Brahmbhatt & Kathuria, 2014). This pace has also contributed to an unprecedented decrease in the poverty rate (from 37% in 2004/05 to 22% in 2011/12); an extraordinary decline over so short a period. The segment of population which overcame poverty corresponds to the middle-class families. On one hand, the present forms of public transport in Indian cities (including buses, suburban trains, and other private vehicles) and the road/rail infrastructure cannot cope with such rapidly increasing demand. On the other hand, around 20-40% of India's emissions are due to the above transport forms. Metro-rail systems are an option that can improve the quality of transportation infrastructure in Indian cities considering that a single four-car metro-rail rake per trip is expected to remove 16 buses/300 cars/600 two-wheelers from the road (Bundhun, 2015). This reduces both traffic congestion and pollution.

India has built around 324 km of metro rail mostly in the last decade, with another 520 km currently under construction in various cities including Delhi and NCR, Kolkata, Chennai, Jaipur, Mumbai, Kochi, Ahmedabad, Nagpur and Lucknow (Metrorailnews, 2016). Additionally, another 553 km is under consideration (Shah, 2016). The Indian government aims to build metros in at least 50 cities across India within

*Corresponding Author: E-mail – mash@iitm.ac.in

the next 10-15 years (Kochhar, 2016). Sankhe et al., (2010) at McKinsey estimates that around 7,400 kilometres of metros and railways will be constructed during this period. This will lead to an unprecedented era of construction activity, which is part of the $1.2 trillion in planned capital investment for meeting the demand of India's growing cities.

The scale of this development makes it important as improvements in design, construction and operations can have a significant impact on built asset sustainability. The current practices of project execution and maintenance generate substantial waste at the behest of the client's preferences and local existing laws that are often loosely enforced (Arif et al., 2012). The construction sites in India are typically congested and located in heavily built-up areas with no provisions for alternate storage or staging location for materials. Often, construction wastes are not and cannot be taken ownership for due to the presence of multiple contractors on site and lack of awareness and education among the construction workforce. Also, waste is transported by open trucks and often scattered in nearby areas (Kaushik, 2016). Debris is frequently dumped along the road-side without provisions for proper disposal. Worse, the lack of waste management programs often leads to waste burning, which is the largest uncertainty in India's emissions inventory. Beyond material waste there are other inefficiencies that lead to time and cost overruns on a majority of Indian infrastructure projects – non-availability of resources on time and poor planning to name a few (Project Management Institute and KPMG, 2014). These are but a few of the symptoms of a less than advanced approach to sustainable development. The United Nations Environment Programme suggests that achieving sustainable design and construction practices in India requires a) bridging the knowledge gap on sustainable building strategies, which exists at various levels within the industry; b) enforcing implementation of strategies to encourage adoption of sustainable, green and energy efficient infrastructure; and c) conducting research and development on technology for lowering costs (Kochhar, 2016).

In order to improve project performance and overcome these challenges, project organizations are now embracing digital tools. While the first generation of digital tools allowed for the digitization and sharing of information (CAD files, spreadsheets), later generations allow for the creation of digital models with shared, embedded information which can be used for enhanced coordination across the project team. Building Information Models (BIM) for instance represent one such paradigm that promises to increase throughput on projects by enabling greater, and earlier visibility of information with a view towards allowing project leaders to optimize decisions (Eastman et al., 2008). Tools such as BIM have been embraced by the international construction community. Several countries such as the UK and the USA have mandated the use of BIM on key projects and iconic structures such as the Disney Concert Hall in the USA and Heathrow Terminal 5, to name a few have used a variety of digital tools in their development (Bryde et al., 2013). As integrated digital delivery approaches are becoming used internationally in infrastructure projects, new questions arise about their application and suitability in these Indian metro-rail projects. To what extent have Indian Metro Rail projects embraced Digitalization in project delivery? How applicable is Digitalization in the Indian Infrastructure context? What pathways can be charted for a digital expansion in infrastructure delivery? This paper seeks to address some of these issues.

2. BACKGROUND

2.1. OVERVIEW OF THE INDIAN METRO-RAIL PROJECTS

Based on the perceived success of the Delhi Metro-rail Project, which revolutionized transport for the 17 million residents of that city, many other cities in India initiated metro rail projects. On 11 August 2014, India's Union Government announced that all Indian cities having a population of more than 1 million would be eligible for financial assistance to implement a metro rail transit system (Elets Technomedia Pvt Ltd., 2014; Indo Asian News Service, 2014; Wikipedia contributors, 2018). Following this, in May 2015, Union Urban Development Ministry's proposal to introduce metro rail systems in 50 cities was approved by the Union Government. Most of these planned projects will be realised through special purpose vehicles, established as equal partnership joint ventures between the Union and the respective State Government. An estimated ₹5 lakh crore (5 trillion rupees, ~US$77 billion) would be invested by the Union Government (Rail News Media India Ltd, 2015; Wikipedia contributors, 2018). As of November 2017, there are 11 operational metros in ten cities (Kolkata, Delhi, Bangalore, Gurgaon, Mumbai, Jaipur, Chennai, Kochi, Lucknow and Hyderabad) in India and has 324 km of operational metro lines (Metrorailnews, 2016; Wikipedia contributors, 2018). Existing metros and the metros under construction and planning are shown in Figure 1.However, many of these metro rail projects are facing cost overruns, schedule delays and safety incidents (Indo-Asian News Service, 2017; Staff Reporter, 2017; Menezes, 2018; Rawal, 2018).

2.2. BIM, LEAN AND BUILT ASSET SUSTAINABILITY

The construction sector has taken active steps to reduce its carbon footprint by minimizing its key sources; construction waste and process inefficiencies. This has been achieved through adopting lean construction principles, moving towards mechanized off-site manufacturing and exploiting recent IT waves, such as Building Information Modelling. In the UK, for example, the use of BIM is predominant and expected to rise to 95% by 2018. Many governments internationally (e.g, Germany, UK, Singapore, Korea and China) promote the use of BIM and related forms of integrated digital delivery in building and infrastructure projects. There is substantial work on standard development, with a new suite of standards (ISO 19650) being developed. The World Economic Forum has recently brought out its own plan to accelerate BIM (World Economic Forum and The Boston Consulting Group, 2018), building on recent work on the future of construction, that articulates the different digital technologies that are available across the lifecycle. Projects like Crossrail and High Speed 2 in the UK have put significant effort into developing information management strategies during delivery.

India has yet to make significant advances in lean adoption and off-site manufacturing and lags significantly behind in the exploitation of recent IT waves. For example, only 22% of India's construction professionals use BIM (Sawhney, 2014). The result is that construction activities in India account for the highest direct and indirect CO2 across all Indian industries at 266 MT/year (24% of the total), while Delhi alone produces 5,000 tonnes of construction material waste every day. This carbon footprint is about to get even worse, as the Indian government is in the process of planning and building metros and railways for 50 cities over the next 10-15 years, which is 20 times the capacity added in the past decade. It is unlikely that existing IT tools and adoption mechanisms in India will manage to change this trend and substantially contribute to reducing the carbon footprint anytime soon: what will make a big enough difference?

2.3. TOWARDS DIGITAL DELIVERY AND LEAN

Hence, this project's primary motivation is that India's construction sector is not ready yet to exploit the ongoing BIM wave to its full potential for sustainable development due to the lack of tools that cater to the needs of a developing country. The second motivation is that there is a parallel gap in the range of technology developments being considered to maximize the benefits of a BIM-enabled digital worksite. To date, research efforts have focused mostly on data models for smart cities, refining BIM standards and applications, data security and sharing, integrating BIM with the cloud and the smart infrastructure; complementary to this is the possibility that worksite models can be generated (or as-designed models updated) throughout construction to help provide the rich data backbone needed for sustainable construction practices, such as workflow automation and quality assurance, and create a resilient, as-is digital record of India's built environment.

A shift towards the use of digital information about assets in rail, which has been enabled through developments in Building Information Modelling and its use on major projects. While integrated digital delivery approaches become used in globally-leading transportation projects, there is a shift in the locus of new transportation projects to developing contexts such as India, raising new questions about how the delivery of transportation systems can benefit from innovation across a broader range of institutional contexts.

BIM is not widely used in the Indian context (Mahalingam et al., 2015). A starting hypothesis, which motivated the international research team to work together, is that if it is affordable to digitize and interact with the digital version of the construction project and the infrastructure systems it affects, more of India's stakeholders will be likely to take advantage of digital technologies, leading to a significant reduction in upfront design costs and design uncertainties, which in turn will lead to better change order and rework control during construction. Objectives are to articulate the mechanisms for and barriers to innovation in the context of Indian metro-rail projects; and to identify opportunities for digital delivery.

Research on BIM in the context of the Chennai Metro indicates that a station that first implemented last planner had better success in its use of BIM than one that started with the use of BIM, perhaps because the lean processes associated with last planner required collaboration that was useful in using BIM (Mahalingam et al., 2015). BIM has resulted in benefits in such isolated cases. Why then have BIM applications not been scaled up and across Indian infrastructure?

Figure 1: Map of India Showing Statuses of Metro-Rail Projects

Previous research has determined that the key factors influencing the lag in construction technology adoption in India are: a) lack of awareness on client side and hence no requirement in contracts to adopt technology; b) no impetus from the government for a phased adoption plan; c) lack of industry wide standards (unlike the UK); d) dependence on international software tools with inadequate local technical support from vendors e) inadequate basic research and development capability by Indian IT industry to develop required platforms; e) focus by construction organizations on short-term ROI; f) little investment in training employees to adapt to new technologies; g) challenge in reengineering workflows to enable digital standards, and h) challenge in customising tools to support existing workflows. The developed world also suffers to some extent from some of the factors above. Yet, technological and procurement solutions and standards have been developed to address most of them, while a stronger focus on innovation and R&D has created a culture of innovation acceptance. The investigators and their peers have made preliminary attempts to address this technological gap through methods for generating and visualising rich Building Information Models (BIM) of existing facilities. The resulting prototypes are robust for practical use and provide early insights on the technical challenges that must be addressed. Yet, these tools are not built for worksites or metro/railway infrastructure. A key research gap, therefore, is to understand the kinds of mechanisms and strategies that can overcome these barriers and lead to greater adoption of Digital Technologies in the context of Indian Metro Rail projects. While we do not claim to comprehensively answer this question in this paper, we hope to understand the state of digital adoption, drivers and barriers and future pathways towards digitalization in the Indian metro context.

3. METHODS

Method steps associated with the data collection and analysis include:

1. Preparatory desk-based research – initial work was done to understand the Indian construction context; and the potential for developing novel technological solutions in this context. The academic team has had many online meetings in shaping the research, proposing and planning for the co-located work in India.
2. Site visits – when co-located in Chennai, India, the team made two site visits, to the major contractor Larson and Toubro Ltd. (number 21 in the ENR's 2017 Top 250 Global Contractors) and to a metro-rail project. Four members of the team visited the contractor together; with five members of the team visiting the metro-rail project, giving shared familiarity with the context of metro-rail construction. The research team varied in their familiarity with the context enabling us both to ask simple open-ended questions, such as 'what was the main issue you faced on this project' and also to contextualise and interpret the answers given.
3. Workshop – this day-long workshop was hosted by members of the research team and attended by 40 participants including client representatives of six major Indian metro-rail projects along with technology providers and delivery teams. This workshop was organized to understand the challenges faced by the current metro projects in India, in adopting and implementing digital initiatives. The workshop also aimed at facilitating a common ground for exchange of ideas and gaps in pushing digitization in Indian metro construction. Leading practices in digital delivery and the potential for their adoption in digital metro rail construction in India were discussed. There were sessions to discuss digital practices in the six Indian metros that were represented; and the key challenges in their adoption of digital tools and methods. Based on the identified challenges, participants were divided into four groups and concentrated discussion on these topics was done and each group presented an outline of their discussion and how the challenges could be tackled. Detailed notes were taken throughout the workshop and audio was recorded. A report of the workshop was written up and distributed to industrial participants.

While collecting and analysing data from the site, the team also read recent research literature, to ground findings in the existing literature and to show where our work extends this existing work to make a contribution to understandings of transportation systems policy and practice.

4. RESULTS

4.1. PRACTICES ON THE CONSTRUCTION SITE

On the site visited by the research team, there had been 1300 people working in total (400 skilled and 900 unskilled). There is transient labour and high construction activity, such that the project managers felt they were short of 300 people. Labour is recruited through a specialist labour subcontractor, which takes responsibility for recruitment, and for managing the accommodation for site labourers. Evidence of the use of digitalization practices on site was virtually non-existent.


(a)

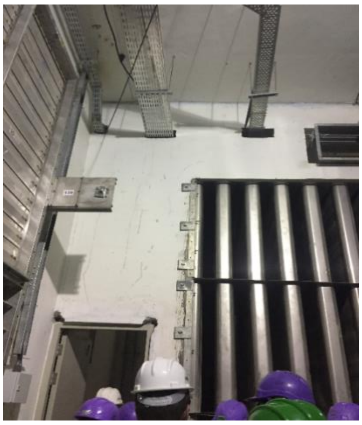
(b)

Figure 2: (a) Metro-Rail tunnel in the 'fit-out' phase; and (b) A detail of the station showing the drilling of holes in the wall for high-level cables

4.2. WORKSHOP DISCUSSION

Indian metro projects are in the very early stages of adoption of digital initiatives. Most of the projects under construction have no digital initiatives in place. However, the projects going into the next phases are planning to include digital initiatives on its agenda. Considering that there is no official mandate by the government for implementation of BIM/digital technologies for any phase in a construction project, usually, client or general contractors drive the initiatives. However, there are isolated digital initiatives followed among the metros for automating the workflows. E.g. Kochi Metro has implemented a digital workflow for submitting documents and managing them. Metros for which Larsen and Toubro is a contractor develop 3D models and use clash detection for identifying clashes between different engineering disciplines at an early stage. Also, Larsen and Toubro have enabled mobile platforms for performing inspections on site.

At present, in India, Nagpur Metro is the only metro rail project which has taken significant steps towards implementing BIM in its planning and design phase. While the client – Nagpur Metro Rail Corporation Limited (NMRCL) did not stipulate inclusion of digitization, private technology providers along with the general contractor took leadership for a BIM integrated project delivery. 3rd party BIM developers such oversaw modelling and process integrations for BIM at the Planning and Design stage and supply-chain management. RFID tags were used to manage the status of component tracking and installation.

The Nagpur Metro Project uses digital information management systems across the lifecycle of the project. Following the BIM strategy developed for the Crossrail project, the BIM strategy for the project was based on the guidelines from PAS1192 standards. The main areas of the use of digital platforms for information management are:

- Design review and approval process are carried out in a common data environment to improve transparency and to enable tracking. Drawings will be attached with placeholders. The document will be transmitted to document controller. Document controller acknowledges transmittal & forwards to Lead Reviewer to initiate approval process. Reports are generated to track the status of review and review process requiring attention are flagged.
- Building Information Model (BIM) is created from 2D drawings and associated data. The following information is mandated to be included in every component (e.g. Geometric data, material definitions, quantity take off, asset tags, links to related documents etc.). The BIM model is intended to be used for planning and clash detection, in addition to the value it has during the operation phase. The work order quantities from the BIM models were used to cross-check with the work order quantities supplied by the contractor.
- To enable visual progress monitoring and integrated cash flow management, building information is linked to SAP software for billing and finance. Also, the building information model is linked to the

Oracle Primavera P6 for integrating the schedule. RIB platform is used as a 5D visualization platform for integrating information form costing and planning. This has enabled them to visualize the progress of the project and detect deviations.

One of the major challenges in Nagpur metro was that BIM was not used beyond the above two stages. As a result, information encoded in BIM was not used to ease the downstream phases such as operation and maintenance. Hence, during subsequent expansions of the metro, verification is required to ensure the validity of Building Information Models.

5. INTRODUCING DIGITAL DELIVERY

Based on the discussions on how digitalization of infrastructure is carried out in the UK and where Metros in India are at in terms of digitalization, the participants were grouped into four categories to brainstorm on opportunities, key challenges during metro construction and how it can be addressed through digitalization as represented in Figure 3.

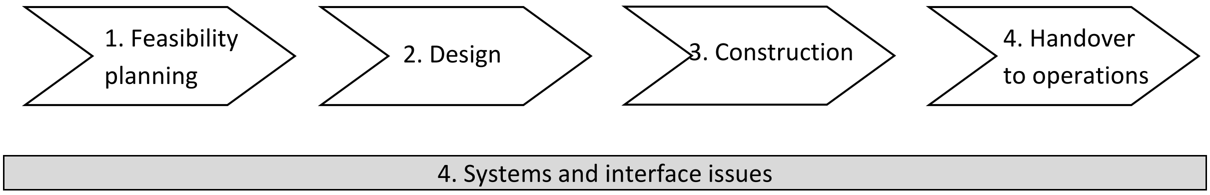

Figure 3: Issues considered at the workshop

5.1. *FEASIBILITY PLANNING AND HANDOVER CHALLENGES*

The problem of lack of land use maps along the alignment of the metros for decision making was discussed. This can be tackled through the use of city-based geographical information systems. One of the main challenges when it comes to digital information is the lack of data retrieval mechanisms over the lifecycle of

Figure 4: Discussions on the Challenges in Progress at the Workshop

the project. Information is embedded into the model at different stages with different tools and most of the data is locked within the tool and cannot be accessed easily.

Group 1 also discussed the lack of platforms for predictive analytics using real-time data and the need for those when it comes to digitalization of metros. The group also touched on the issues of stakeholder – technology management and the need for a proper strategy for stakeholder-technology management for successful digitalization of metros.

5.2. DESIGN CHALLENGES

Availability and reliability of design information were one of the key challenges in the construction of metros, particularly when this information comes from different sources. The group also discussed design automation for generic designs such as viaducts instead of manual designing using spreadsheets and the role of digital tools in enabling it. Lack of organization-level customization for digital design tools was identified as a challenge in the context of design automation. This leads to the need for high level ontologies for design flow-process mapping.

The group also discussed the classic problem of information loss and interoperability when digital tools are adopted. This reinforces the need for open standards for digital information. In the end, the group discussed about generative design which solves the time and cost problems arising due to redesigning when changes and revisions are brought forward.

5.3. CONSTRUCTION CHALLENGES

One of the main problems which came up during the discussion was regarding the uncertainties in the underground soil profile as well as lack of information on the underground utilities. This has both a cost and schedule impact, the schedule impact is particularly massive, and its derivative cost impact, because the utility owner takes forever to make a change. Utility risk is put on the contractor. If the time between inception of the project and construction can be used to divert the utilities or creating alternate alignment this problem could be solved. India needs an accurate geo-information system to map its utilities.

The second issue discussed this group was on Progress Monitoring methods of compiling the progress updates from different sub-contractors and reporting it as an aggregated report of the contractor. Also, updating the information across different levels of documents/models was discussed as an issue which can be tackled using automation. The next topic of the discussion was the lack of construction friendly models and tools. The use of specific schemas that allow users to load inspection tasks and the model automatically showing relevant objects and dependencies at the right LOD level for each object type and relationship type would help increase the use of model at a construction site. In addition, there is a concern on how to sense the construction data and link them back to the model.

5.4. SYSTEMS AND INTERFACES CHALLENGES

One of the key areas of discussion was the lack of contractual provisions to include digitalization as an agenda on projects. Following practices in the UK, Group 4 discussed on adding clauses mandating digitalization as additions or as an appendix to contracts for the projects whose contract is already made. Development and adaption of standards was the next point of discussion. Although PAS 1192 acts as a good base of standards for digitalization, whether it could be adopted by Indian construction industry or should it be customized for Indian context was discussed. The group concluded that there should be an element of customization when it comes to standards. Defining a technology strategy for a project was found as a necessity for digitalization, and organizational culture should also be altered to integrate digital processes and workflow. Education of key stakeholders on digitalization was another point brought forward by the group. It is necessary for the client to understand the potential and capability of BIM and the workforce has to be given awareness on BIM. The responsibility for providing awareness and training on BIM workflows should be taken up by contractors and owners as a part of their social responsibility by opening BIM academies. One such has already been opened by Nagpur Metro and Larsen and Toubro ECC.

6. CONCLUSIONS

The penetration of digital technologies on Indian metro rail projects today is minimal. Barring the Nagpur metro, the other metro rail projects currently underway in India have hardly scratched the surface of Digital technology. However, the discussions in the various groups indicate that there are several challenges that such projects face that can be addressed through digitalization. Digital land use maps can lead to better planning, automated or generative design can lead to swift generation of alternatives, 3D and 4D models can help ensure timely progress on the sites and so on. Furthermore, the discussants from the various metro rail projects showed awareness of digital technologies and indicated a willingness to adopt digital technologies for these needs. However, it was clear that a single solution such as BIM may not be a silver bullet in these cases. A bottoms-up construction of a holistic Digital System that integrates tools such as BIM with GIS and other workflows specific to a project will be necessary in order to ensure adoption by the project team and to improve project performance. Design-thinking based approaches may need to be brought to bear in designing such systems that will not only be useful but will also be used. These are potential directions for future R&D. The ambitious metro rail program in India has opened up a plethora of opportunities for digital technology. Practitioners are aware of these technologies and barriers to adoption, though significant, can be overcome. It is now up to technology providers, academics and practitioners to take advantage of this situation to combine tools in innovative ways to create context-based solutions that accelerate digital adoption and also improve project performance.

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VALUE CONSIDERATIONS OF ADOPTING BIM IN FM

K.A.D.N.C. Wijekoon*, Anupa Manewa, Andrew Ross and Mohan Siriwardena

Department of Built Environment, Liverpool John Moores University, United Kingdom

ABSTRACT

Building Information Modelling (BIM) is expected to streamline the key processes of construction, and promote innovation throughout the building/product life cycle. Since most buildings have been designed for long lifecycles, the facilities management (in-use) phase is significant. Therefore, use of BIM in facilities management (FM) offers the promise of much benefits to project stakeholders. Even though strategic level benefits of BIM to FM are recognised, limited attempt has been made to understand its application at operational level.

This paper aims to establish the "value" of BIM in FM. The study explores the key aspects of value theories through a thorough literature review and empirical data from 15 interviews to identify the human value consideration of BIM in FM. The background of this paper discusses the nature of built environment by bringing evidence for the value factor embedded in buildings beyond price. Wider benefits of BIM in facilities management are noted, however its implementation within FM phase is limited. The findings of research explain the critical value considerations for BIM in FM by considering the value of BIM at operational level. The research contributes to the current knowledge by presenting the key link of basic human values with operational level BIM expectations.

Keywords: *Basic Human Value Theory; Building Information Modelling (BIM); Facilities Management (FM); Value In-use.*

1. INTRODUCTION

Building Information Modelling (BIM) is a popular information creation and management tool within the Architectural, Engineering and Construction sectors (McGraw-Hill, 2009). The capabilities of BIM are widely used during the design stage to manage and validate building design (Vanlande *et al.,* 2008). Although the application of BIM is dominant in early stages of a building construction (i.e. Concept, design stages), owners and facilities manager have good potentials in achieving benefits of through-life BIM adoption (Eadie *et al.,* 2013; Howard & Björk, 2008). However, the overall benefits of BIM are not completely identified and construction project stakeholders are still struggling to make decisions on possibilities for adopting BIM within their project execution plan (Barlish & Sullivan, 2012).

Research in psychology proves that people make choices based on the basis of fulfilling psychological needs (Deci & Ryan, 2000) which are identified as values. Therefore, this research aims to reveal the reasons behind the slow adoption of BIM during the facilities management stage, by studying the psychological needs in FM concerning BIM. Benefits of BIM are reviewed and compared with an advanced and empirically proven human value theory. Value perceived in buildings is studied first to set the credibility of applying human value theories to motivate decision on BIM adoption. This study identifies the broad term of BIM as the combination of information, technology and process of creation and management of digital footprint of a facility as a step forward into smart cities.

Recognising construction as an ancient human activity emphasise the sociological aspect of the construction. It is a discipline close to human lives and therefore build upon human needs. Construction was initiated to fulfil the basic need for shelter to protect from changes in climate. Contradictorily, living in the 21st century,

*Corresponding Author: k.a.wijekoon@ljmu.ac.uk

construction is another specialised activity take place out of everyday life. This study attempts to bring forward the human element of built environment which is underestimated in time, cost, quality culture in construction. This is achieved by focusing on the current trends in adopting Building Information Modelling (BIM) in built environment.

2. RESEARCH METHODOLOGY

Research methodology explains the logical thought process followed to reach the research output (Sutrisna, 2009). This paper presents a part of a research project which aims to evaluate the impacts of implementing BIM in FM, especially the human value considerations of such implementation. To begin with, a literature review on built environment and BIM has been conducted to gain an insight on how value of BIM is being interpreted. Having identified the knowledge gap in terms of the absence of an explanation as to the low level of BIM implementation in FM, the study was taken forward by following a qualitative methodology. Following a snowballing sampling method, 15 interviews were conducted with operational level facilities managers using open ended interview questions to identify FM's perspective towards BIM. As role of FM is multidisciplinary, the designation given for this role at each organisation tend to differ. All interviews were based on the primary question of "*How can BIM be valuable to your daily operations?*" and prompt questions were asked to direct the interviewee towards the key question.

Qualitative research is used to study complex situations due to its capability to reach rich data (Sutrisna, 2009). In qualitative research, philosophical view point is important in order to understand the assumptions and reliability of the findings. This research is based on a critical realism philosophical view. Critical realism merge the positivism and constructivism to identify the truth (Fletcher, 2017). Accordingly, the researcher takes the view that there is a single reality but multiple explanations. Data collection and analysis methods have followed the grounded theory strategy to capture the multiple explanations. Therefore, 15 interviews were analysed using three stage coding method recommended in grounded theory. With critical realism comes the assumption that theory makes reality more accessible (Fletcher, 2017). Therefore, findings were matched with the Schwartz's Basic Human Values theory understand the FM perspective of BIM. As the Facilities Managers are not at the capacity or position of making the decision of procurement of BIM, this study is limited to understanding underline motivations of taking forward BIM into operational phase of a facility. Also, previous research has emphasised the limitations of economic value considerations of BIM due to lack of whole life cycle experience to quantify its benefits (Becerik-Gerber & Rice, 2010). Hence, human value theory is being utilised over economic theory.

3. NATURE OF BUILT ENVIRONMENT

The core purpose of this study is to bring new insight into the existing knowledge pool to improve the creation and operation of the built environment. To begin with, this topic builds up the background of the study by exploring what it is meant by "built environment", how it evolved and nature of the 21st century built environment. This complete exploration is expected to take out the conclusions made studying only the tip of the iceberg. There is a remarkable difference between early construction which was identified as an ancient human activity of creating shelter into what is constructed in first century in the third millennium. The importance of studying this difference is to understand the decay of core values interacted between humans, natural environment and built environment. The research on anthropology of built environment hold evidence to how construction of space move from shelter to representations of the social order (Ashworth, 2011; Lawrence & Low, 1990). The development of human needs changed the forms to accommodate them. Built environment is not any more accommodating functional requirements but perceived value (Ashworth, 2011). In contrast, some literature argues that development of the built environment is purely based on material and technology advancement.

The modern construction of built environment is being pushed forward with the technology advancements, limitations in resources and possibility of implementing complex designs giving less concerns towards core human concerns. Since broader spectrum of complex human needs are narrowed down to quantifiable measurements of cost, quality and time in today's construction industry; it is a question whether the stakeholders understand the underpinning human needs communicated through cost, quality and time (Horne *et al.,* 2014). Rapoport (1982) presents an interesting study on meanings of built environment defined by different user groups. One of the examples it presents is the findings of a survey done in France on preference for living in small-detached houses. It holds evidence to how building user express the meaning of space around the house through "clean air". Revisiting the house spacing over the time shows how knowledge and technology has influence the decision but, with the uncertainty of whether technology have compromise the human needs over ease of implementation (See Figure 2). Giving priority to understand the human element of the built environment, this broader view of the built environment is then narrowed down to means of creation and use of information in built environment to focus on the element of the study.

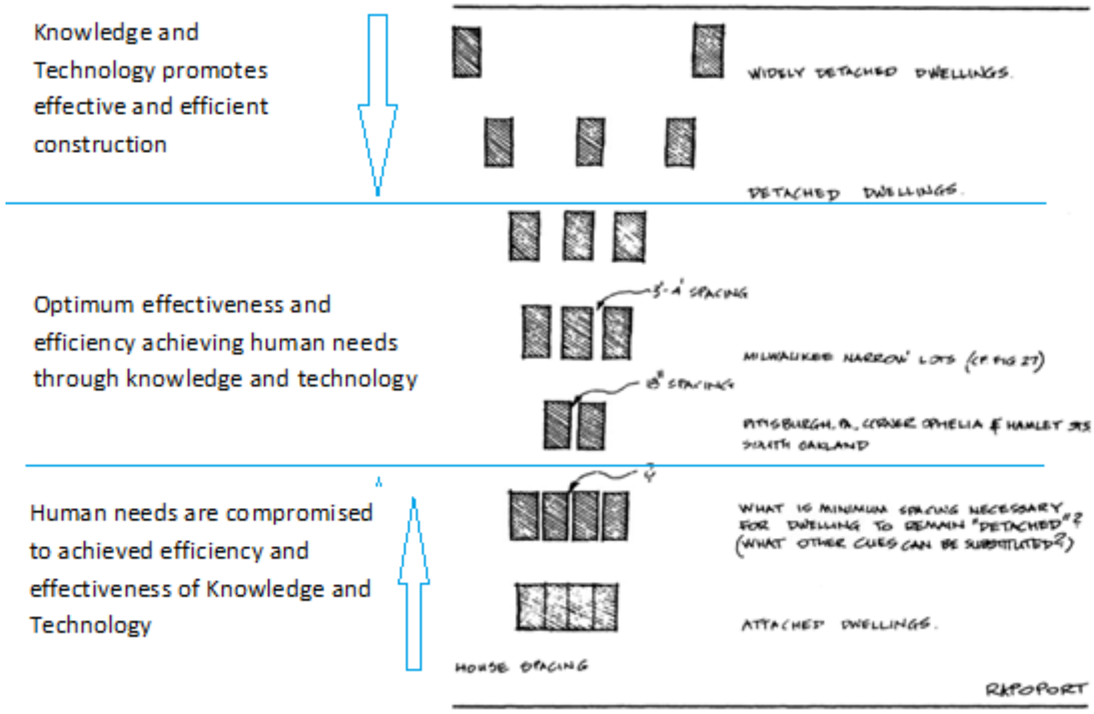

Figure 1: Space Necessary for Meaning of 'Detached'

Source: Adapted from Rapoport (1982)

With the development of the human civilisation and construction capabilities, the purpose of construction was gradually changed from constructing a means of shelter into a communication medium and representation of social value. Studying through the building anthropology confirms that built environment has value which is not completely appreciated by price (Horne *et al.*, 2014).

In an extensive sense, built environment refers to any form of man-made alteration to the natural environment (Lawrence & Low, 1990). This includes forms of products (buildings) such as dwellings, shopping malls, theatres that are enclosed space and roads, parks or plaza that is a defined space but not necessarily enclosed. Most of those products are designed for long lifecycles and in-use phase takes considerably a long duration. To build such products, proper processes/systems are required. The technology advancement helps this by inventing several tools, mechanisms and processes time to time, and BIM is seeming as one of the latest.

4. HUMAN VALUE CONSIDERATION OF BIM IN FM

The concept of "value" took the interest among scholars since the beginning of social science research (Schwartz, 2012). Value is described in many ways and most common descriptions could be categorised as either value in exchange or value in-use. Becerik-Gerber and Rice (2010) presents perceived value of BIM through analysing tangible benefits and costs which can be monetised. However, most of these research on value does not provide a precise description what is meant by value. One of the key characteristics of values is that there are common features in value as well as a distinguish difference. On the other hand they work in a circular structure where one value motivates the other (Schwartz, 2012). Although 'value' is an everyday term, this nature of value is what makes it complex to pin down what it means every time when the term value is used in communication. Studying similarities of values help defining values. Schwartz (2012) explains six features common to all values;

Values are beliefs: Values are deep rooted with feelings. A person who recognise independence as an important value, is delighted when they can enjoy freedom and arouse when their independence is threatened. This leads to both positive and negative behaviour based on the emotional charge.

Values refer to desirable goals: Values motivate actions. When social acceptance is an important value, one will act and behave to gain social acceptance at all circumstances.

Values transcend specific actions and situations: Obedience and honesty may be relevant values in work place but these values are not limited to workplace decisions. This is one of the features distinguish between norms and attitudes which are usually refer to specific situations or objects. For example; one who value lowest cost will make decisions based on price in both personal matters as well as business engagements regardless.

Values serve as standards or criteria: Values guide the people to decide what is good or bad, worth doing or avoiding. However, this logic between values and everyday decisions are rarely conscious. People are only aware about the contribution of values when the judgement to be made has conflicting implication for different values one believes in.

Values are ordered by importance: People prioritise the values based on their character or ordered system of priorities build person's character. These priorities change with the context. Hierarchy is another key feature that distinguish values from attitudes and norms.

Relative importance of multiple values guide actions: Choices made are typically implications of more than a single value. It could be purely combination of values gained as well as combination of values gained at the expense of another. This emphasise the importance of recognising values of FM in order to influence their motivation towards adoption of BIM in FM.

The efforts made on understanding value of BIM in monetary terms has identified that it is too early to determine the tangible value of BIM as it is still in initial stages (Becerik-Gerber & Rice, 2010). Therefore, understanding the value of BIM cost savings may not provide the reasons for immediate adoption of BIM in FM. Creating knowledge on how BIM caters existing human needs in short term is being recognised as a timely solution. Schwartz's theory of basic human values identifies ten basic human values which are empirically proven to be common among cultures (Schwartz, 2012).

Table 2: Ten Basic Human Values

<table>
<tr><td>Self-direction</td><td>Independent thought and action which allows to be creative, explore and choose</td></tr>
<tr><td colspan="2">This value is motivated in humans as intelligent subject. It seeks for self respect, privacy, freedom and promotes creativity. Self-direction is a commonly seen value which influence most of the actions and decisions.

In BIM terms; It is similar to the general explanation. As an example, adopting BIM because it allows creativity</td></tr>
<tr><td>Stimulation</td><td>Excitement, novelty and challenge in life</td></tr>
<tr><td colspan="2">This is derived in relation to self direction. People make choices to make life exciting and varied. The choices which satisfy this need is valued. This is again might find contradictory with Tradition as people value to commit to what they know.

In BIM terms; Exciting opportunities open through BIM adoption. For example, being nominated for best practice awards or overseas training opportunity</td></tr>
<tr><td>Hedonism</td><td>Pleasure and gratification for oneself</td></tr>
<tr><td colspan="2">This comes from the person-centered needs. Ability to satisfy one's needs motivated to make choices.

In BIM terms; ability to make user's life easier is a motivational factor to adopt BIM</td></tr>
<tr><td>Achievement</td><td>Personal success gained through demonstrating competence according to social standards</td></tr>
</table>

Skills and competences are required for survival and resource generation. Performing to achieve survival and resource generation brings social recognition. Therefore, people act and make choices to gain social recognition. In BIM terms: Skills and competence gained through BIM is a value and recognition as a BIM expert	
Power	Social status and prestige
The most simple explanation of this value is need for dominance over resources and people. In 21st century this is more seen through developing social status. Although this finds similar to the "Achievement" value, "Power" focus on preserving the social esteem while "Achievement" is towards active engagement to gain social esteem. In BIM terms: Power held by having undocumented knowledge about the building	
Security	Safety, Harmony and stability
This value refers to the individual interest of safety such as being clean as well as wider interest towards national security. In BIM terms: Stability with current system is valued over unknown BIM	
Conformity	Restrain of actions and impulses likely to upset or harm others
This informs the natural tendency to act in a way that violate social expectations. Conformity is a motivational factor to self discipline and politeness In BIM terms: This could be defined as honor line manager's non-BIM agenda although that's not ones preference	
Tradition	Respect, acceptance and commitment of the customs and believes according to one's culture/religion
Every person has his own beliefs. Practices and ideas. Common beliefs bring groups together and they express their unique worth. It is a form of subordinating to social expectations in terms of culture and religion rather to persons as it is in "Conformity". In BIM terms: Generational difference in acceptance of technology	
Benevolence	Looking after and developing the welfare of those with one is personal contact
Expressed through the voluntary concern towards others' welfare. Primarily within the family and extended society. This value promotes people to be honest, forgiving, responsible and loyal. Where as in conformity is acting forgiving and responsible to avoid negative outcomes. In BIM terms; adopting BIM purely because of understanding its value as the right thing to do	
Universalism	Understanding, appreciation and tolerance of whole universe (people and nature)
As a survival mechanism to avoid life threatening conflict from people and destruction of the resources from the nature. The realization of this value is only perceived with the experience of resource scarcity or encounter of others beyond their group or at a natural disaster. In simple terms this could be paraphrased as appreciation of social justice and world peace. This value content the subtypes of inner harmony and spiritual life. In BIM term; adopting BIM for recognizing its wider good through universal application and waste reduction	

Schwartz's human value theory was initially developed to present the universal aspect in basic human values. However, human value theory is now being applied in different disciplines to identify human factor in the subject studied (Hicks *et al.,* 2015; Mills *et al.,* 2009). Indeed, research conducted applying Schwartz value theory in construction industry (Mills *et al.*, 2009; Panahi *et al.,* 2016) prove the applicability of the theory in understanding complex social reality in construction industry.

5. BENEFITS AND BARRIERS OF BUILDING INFORMATION MODELLING (BIM)

Building Information Modelling (BIM) is a set of digital tools and processes used primarily in design and construction stages (Kensek, 2015). Based on this definition, Kensek (2015) explains the critical role of BIM in FM pointing out the potential gains from BIM that FM can expect. Some research highlight the benefits of

BIM for FM related to specify function; for instance, in terms of how BIM improve the quality of life of building user (Aziz *et al.,* 2016). Gerrish *et al.* (2017) discuss the ability of BIM to contribute to both design and operation of buildings through visualisation and information management. BIM is still underutilised therefore, complete package of BIM offer is yet to understand (Becerik-Gerber & Rice, 2010).

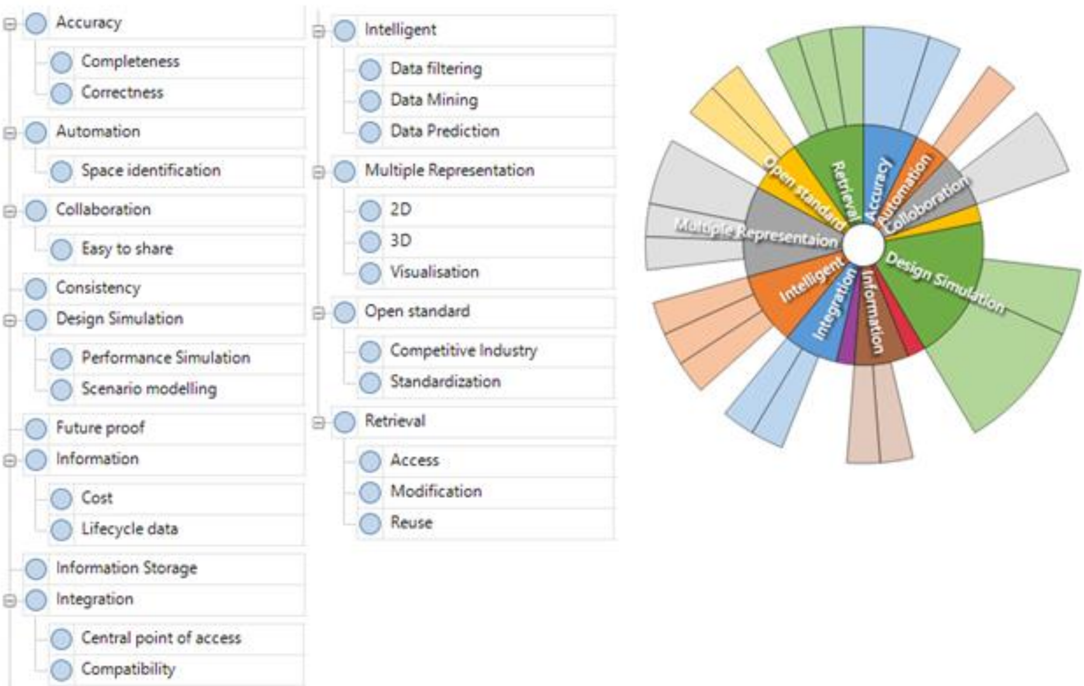

Figure 2: Literature Analysis on BIM Benefits

Figure 2 illustrated the thematic analysis of the literature discussing BIM benefits. The analysis is conducted using NVivoPro 11. It is evident that BIM offers a strong way forward specially with the Smart Cities agenda. However, most of the literature discuss the generic benefits of BIM. Although the study included majority of FM related BIM literature (Aziz *et al.*, 2016; CRC Construction Innovation, 2007; Gerrish *et al.*, 2017; Kassem *et al.,* 2015); each of them discuss on how to use BIM in a ways that offers benefits to FM rather attempting to understand what FM expects from BIM. In terms of barriers to implement BIM in FM; lack of tangible benefits, knowledge on implementation, technological issues with interoperability and skill shortage are highlighted (Kassem *et al.*, 2015). Generational differences, steep learning curve and pull and push between those who are ready to adopt and not, have also been identified as barriers to implementation of BIM in general (Becerik-Gerber & Rice, 2010).

6. FINDINGS AND DISCUSSION

Findings from literature and interviews were merged to develop the value model (Figure 2). As illustrated on the model; in this research, BIM is recognised as a bridge of information, technology and process that were acting in silos before introducing BIM. Interviewees confirming the literature findings on BIM definitions repeated these elements of BIM. For example; the quotation below is from an estate manager explaining the reasons for having not adopted BIM so far.

"..no BIM skills within the staff. We already have 4 or 5 different software packages in use for FM but no one to look after them…Possibly need a strategic manager to manage these systems and update the information….we get promised to give the information but we never get - we get patchy information"

This emphasise that BIM is immediately recognised as technology and then for information it carries. Each of these elements of BIM are referred with its' features when discussing barriers and benefits. For example, Information element carries features such as data, visualisation and information recreation. Another key pointed out in interviews was that, with adoption of BIM, availability of data is expected to increase however, the accuracy of data is not being guaranteed. Extraction from a project manager's interview quoted below holds evidence for this practical barrier in continuous use of BIM.

"We struggled to get all these information most often. We expect the consultancy we employed to check that information to ensure that they are right…. Quite often they have spend time on getting the information, won't spend anymore time checking the accuracy… occasionally when we go out for maintenance, these information aren't correct."

Likewise, data gathered through interviews emphasised that all elements of BIM tend to have promoting as well as challenging aspects in the process of adoption of BIM in FM. However, the manner which each individual or organisation distinguish between challengers and enablers differed with its' characteristics. Market leaders such as contractors with FM service branch tend to see the opportunity in BIM challenges while late adopters doubt the assurance of BIM enablers.

On the other hand, it was noticed from the interview data that facilities managers' expectation on receiving full BIM complied building is purely contractor's responsibility. This is emphasised in previous extraction from project manager's narrative; *"We expect the consultancy we employed to check that information to ensure that they are right"*. This pattern of passing of responsibilities among stakeholders were noted throughout interviews.

In contrast, according to capital project information delivery plan explained in PAS 1192-2; information delivery begins from client's side by producing Employer Information Requirement (EIR) (Manning, 2014). Therefore, facilities manager goes around the value model as an information provider as well as an information user. This emphasise the importance of recognising the value of the role played at each stage.

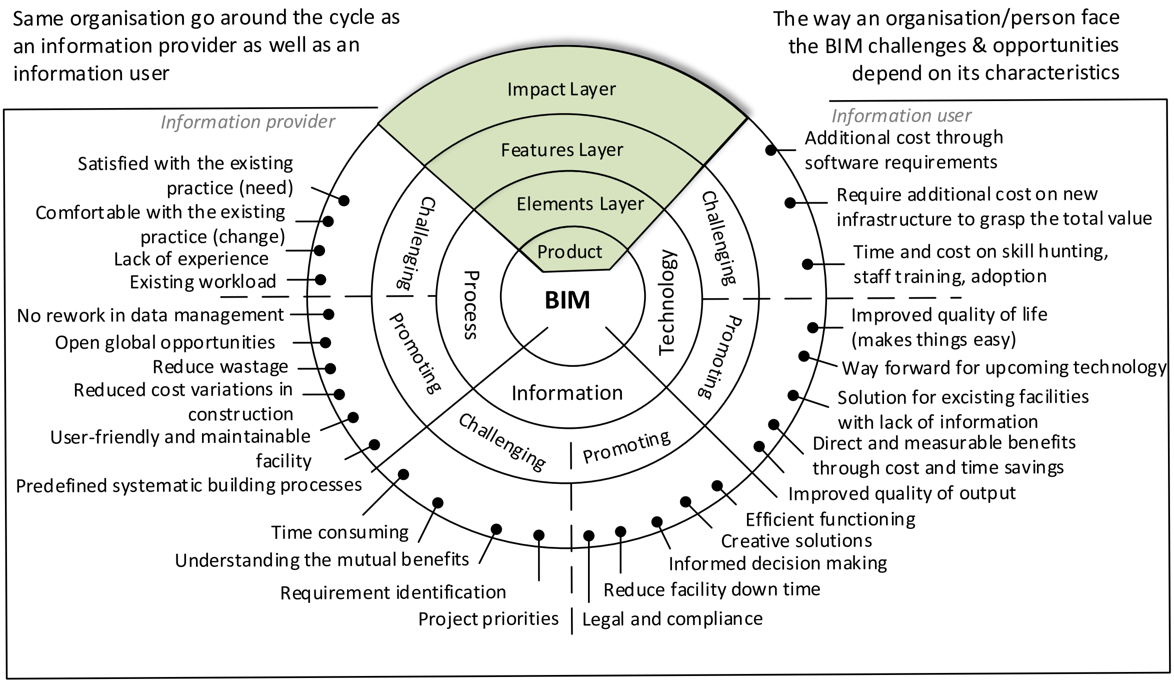

Figure 3: Conceptual Value Model of BIM in FM

Enablers of BIM implementation among operational level facilities managers gathered through interviews aligned with the general BIM benefits that were found through literature review. However, the interviewees discussed a different set of challengers. Although, it is possible to argue that challengers are also similar to the generic BIM barriers; the open-ended interview questions gave them the opportunity to explain it rather limiting their idea by ticking the most relevant barrier on a given list.

Once the value model was developed; challengers and enablers discussed by the respondents were reviewed along with Schwartz'S basic human value theory to understand the potential relationships between psychological needs and BIM values.

A simple content analysis reveal that ultimately what people are trying to achieve through adopting BIM is to satisfy their psychological needs. For instance, mapping the BIM enabler *eliminate rework* with basic human value *Hedonism* explains that less work, less stress is an open path to enjoy life. Which means adopting BIM is not to reduce rework in order to utilise that time on some other office based work but for personal pleasure. However, this is still a benefit even in organisational level form waste reduction and allowing space for staff to be creative. New knowledge to add here is that not to underestimate or ignore personal motivations as it helps to create a win-win situation.

The exciting disclosure was that there is a clear reflection of human values and challengers in adopting BIM in FM. All most all the respondents began their view of barriers with cost and project priorities at first emphasising these factors are key ones while leaving skill shortage and lack of experience towards the end. Looking at this through human values reveals the manipulation of responses to fulfil the values of *power* and *achievement.* In conclusion, overlaying the basic human value theory help grasping true meaning of benefits and barriers of adopting BIM in FM.

7. CONCLUSIONS

BIM in FM is becoming one of popular considerations within the built environment process improvements. Having studied the literature on BIM benefits and argument on lack of adaptation of BIM in FM; the work presented on this paper aims to reveal the social value considerations of limited adoption of BIM in FM. Almost all the work done in BIM holds evidence for its positive contribution to the industry and promising benefits to be achieved. However, FM has not taken into BIM as anticipated.

The paper reveals an attempt to understand the values held by operational level facilities managers. It matches BIM benefits with universally recognised human value theory to map the expectations of technology with basic human values. Overlapping basic human values with BIM benefits helped to develop a clear picture on why that long list of benefits of BIM makes no sense to FM. The findings confirm previous research findings that BIM is not designed to cater the FM needs but all its key features are purely in benefit of design and construction needs. Therefore, adopting BIM in FM will not solve FM needs immediately but have to structure the FM needs to fit with BIM capabilities.

In contrast, the full BIM experience as it was designed was in benefit of FM and long term users involved throughout building life cycle. In depth studies of structure of values shows that sometimes values conflict with each other while others support each other (Schwartz, 2012). This knowledge on values brings new insight towards human classification on benefits and barriers. When values are the deep rooted cause of motivation towards this classification; the new knowledge recognise barriers as benefits which are not yet met.

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WORKER AWARENESS OF WORKMEN'S COMPENSATION IN THE SRI LANKAN CONSTRUCTION INDUSTRY

Nethmi Amanda Wanigasekara, Thilina Laksiri Dissanayake and K.D. Hiruni Ridmika*

Colombo School of Construction Technology, Sri Lanka

ABSTRACT

Work-related injuries and illnesses are common in the construction industry, which can lead to deaths, injuries or disabilities (temporary or permanent) to the workers and Workmen's Compensation Ordinance (WCO), deal specifically with employment injuries. There is no mandatory insurance clause in the WCO that requires employers to be insured against Worker injury risks. However, insurance companies offer Workmen's Compensation Insurance (WCI) policies to cover workmen's compensation liabilities and employer may opt to insure his liability at his own discretion. The aim of this research is to identify the awareness of Workmen's Compensation (WC) among Workers in the construction industry. This research has been carried out through literature review and data collected from a preliminary interview, questionnaire survey followed with semi structured interviews. Research findings show that most workers have a poor awareness about WC; therefore, benefaction from WC to the workers has to be improved. The main reasons for this matter is that the Workers are not retaining under same employer for long time duration and there are no awareness programs in the construction sites about WC. In order to overcome this issue, mainly safety officers can comprise short seminars about WC once in four months in the monthly meetings and safety officers should come across as an intermediary to make sure that the workmen's compensation process is being carried out as required in the site.

Keywords: *Construction Industry; Worker Awareness; Workmen Compensation.*

1. INTRODUCTION

Work-related injuries and illnesses are common, and yet never completely avoidable (Fernando, 2016). Many of the accidents in the construction sites are unplanned occurrences which involves movement of persons, objects or materials which may result in injuries, damages and losses to properties or people (Hosseinian & Torghabeh, 2012). The injuries and illnesses can lead to death of workers with consequent implications for their dependents, or result in injury or disability that may be temporary or permanent (Fernando, 2016). According to Rameezdeen *et al*. (2003), the number of fatal accidents in the construction industry is higher when compared with the other industries. The report in their research shows that fatal to non-fatal accidents ratio in the construction industry is 1:13 compared with the overall 1:115 with the other industries. According to Warakapitiya (2016) out of the 70,000 accidents happened in the first three quarters of the year 2016, 12% has been from the construction sites. Accordingly, it states that many of the construction site injuries are unreported to the labour ministry via the industrial commissioner despite the safety policies of Sri Lanka is of high standard even compared with developed countries.

Warakapitiya (2016) also emphasizes that employers are also not vigilant on the possible dangers and takes a casual approach in minimizing the accidents. Silva and Nawarathne (2014) affirms that underreported construction accidents are significant. The reason for this wrongful act is because the most medium and small companies that hire labourers easily settle matters by paying meager compensation and neglecting an injured labourer's condition (Chandrasekera, 2015). Therefore, it is evident that the knowledge of reporting accidents and claiming insurance needs to improve among workers. Also, it is of major importance to identify the workers awareness about the Workmen's Compensation (WC) in order to find appropriate solutions.

*Corresponding Author: E-mail – bluecaprox@gmail.com

2. LITERATURE REVIEW

2.1. WORKMEN'S COMPENSATION ORDINANCE NO. 19 OF 1934 (WCO)

Workers Compensation Ordinance No. 19 of 1934 (WCO), is the only legislation facilitating all legal repercussions associated with employment injuries (Fernando, 2016). According to Fernando (2016), if a person's injury is arising out of employment and during the course of employment he is entitled for compensation under the WCO; however, the total or partial impairment of the worker has to be more than three days. If the Workman has been negligent in carrying out the work and got injured, as a result WCO prevents him from claiming compensation. Moreover, Fernando (2016) had stated that, the application of WCO in different situations is decided by the case laws, decided by the court of Appeal and the Supreme Court, and this is required due to the fact that the interpretation of certain clauses requires legal expertise.

2.2. WORKMEN'S COMPENSATION INSURANCE (WCI)

Workmen's Compensation Insurance (WCI) is one of the common methods that are available to cover workplace related injuries/accidents and diseases (Wijekoon, 2017). There is no mandatory insurance clause in the WCO that requires employers to be insured against Worker injury risks and an employer may opt to insure his liability in this regard at his own discretion (Thowfeek *et al.,* 2014). Nevertheless, to make the process more convenient, insurance companies offer Workmen's Compensation Insurance (WCI) policies to cover WC liabilities (Thowfeek et al., 2014).

2.3. APPLICATION OF WCI IN CONSTRUCTION INDUSTRY

In the construction industry, the four leading causes for workers deaths were falls, being stuck by objects, electrocutions and getting caught in/ between equipment (Jones, 2016). The fatal injury rate for the construction industry is higher than the national average in this category for all industries and the other potential hazards for workers in construction include trench collapse; scaffold collapse; failure to use proper personal protective equipment; and repetitive motion injuries (United States Department of Labour, 2005).The seriously injured construction workers in the construction industry are unable to return to their former job and may never be able to work at any occupation. This is where WCI and liability insurance plays a major role in compensating workers for their job-related injuries. The Center for Construction Research and Training (2007) stated that employers in construction industry spend more cost on workers' compensations than employers in any other industry.

2.4. LIABILITY OF THE EMPLOYER AND THE BENEFITS FOR THE WORKMEN AS PER THE WCO

The law requires Employers to carry WCI to cover the medical expenses and lost wages of Workmen who are injured in work-related accidents or who develop a work-related illness (Blumenshine, 2014). He had further mentioned that the worker does not have to prove the injury or illness caused by the employer's negligence and the employer may not claim the worker negligently contributed to his own injury. It is a no-fault system that is designed to provide compensation without all the formalities and procedures that apply to court litigation. This position of Employer's liability to pay compensation is enacted under the Part II of the WCO subjected to exceptions.

Additively, injuries or illnesses established as compensable under applicable workers' compensation require prescribed benefits be paid to the injured Workman (Boggs, 2015). He had stated that benefit limits and duration vary by different jurisdictions, however provides essentially the same three "classes" of benefits which are Medical benefits; Disability/Indemnity benefits; and Death benefits. WCO provides for the aforementioned benefits in terms of section 3, 4, and 5 for the death not for a reason attributable for Worker, total and partial disablement which exceeds a period of 7 days. It also extends to occupational diseases in the Schedule III of the act, subjected to provisions. The amount of compensation is to be decided based on the sections in the Part III of the WCO. Moreover under the Part IX of WCO has given authority for the Commissioner of WC to license insurance organization for the purpose of covering indemnity of Employer in respect of his liability to Workers under the WC Law and expediting provisional benefits for the affected Workman.

Therefore, it is evident from the above discussion that WCO and the WCI are the pillars of processing Workman Compensation in the construction industry. Accordingly, the liability of the Employer and benefits of WC in construction industry and their attributes hold the employer responsible to pay compensation even though the worker is unaware about workmen compensation if it satisfies the conditions under the WCO.

3. RESEARCH METHODOLOGY

In order to accomplish the aim of this research study, initially a literature review was conducted to find out the applicability of workmen's compensation in the construction industry and to infer the liability of the Employer and the benefits for the Workman by the WCO. Furthermore; a preliminary interview was carried out with two experts from the insurance industry. The purpose of this interview was to understand about the workmen's compensation in the perspective of the insurance industry. The interviewees of the preliminary interview are presented in the following Table 1.

Table 1: Profile of the Interviewees (Insurance Experts)

Interviewee	Position	Experience
Expert A	Life Insurance Manager, Company A.	15 years in the insurance industry
Expert B	Insurance Sales Manager, Company B.	10 years in the insurance industry

Based on the literature findings and the preliminary interviews a questionnaire was prepared and distributed in 4 sites around Colombo, Sri Lanka, where 50 workers randomly gathered from each site irrespective of their discipline. The main intention of the questionnaire was to identify the workers' awareness about compensation. With the roughly calculated results of the questionnaires, a semi structured interview was carried out with safety officers of three of the four sites, in the other remaining site; the site officer was on leave at the time of questionnaire survey. The interviewees are presented in the following Table 2.

Table 2: Profile of the Interviewees (Safety Officers)

Interviewee	Position	Experience
Expert C	The safety officer of Company C building site.	15 years as a safety officer
Expert D	The safety officer of Company D building site.	5 years as a safety officer
Expert E	The safety officer at Company E building site.	5 years as a safety officer

4. DATA ANALYSIS

4.1. PRELIMINARY INTERVIEW ANALYSIS - WORKMEN COMPENSATION IN THE PERSPECTIVE OF THE INSURANCE INDUSTRY

Expert A stated that the insurance companies in Sri Lanka carries out WC and Contractors' All Risks insurances separated from life insurance. Expert B mentioned that the WC and Contractors' All Risks insurance is falling into the general insurance category by the government act. Regarding the observations of Expert A, the insurance companies which provide general insurances had subjugated to separate director board as an independent insurance company and these both life and non-life insurance systems have adduced by the local government through an act.

According to Expert B contractor's workforce amount is a main requirement to obtain WCI from insurance companies in Sri Lanka, and workers will be entitled to accept compensation if they have used suitable safety equipment and the accident should happen during the regular work at site. Moreover, Expert B mentioned that WC only specifies for illnesses which cause by conducting the same work for a long time and for the accidents during the work, but not for the disability arose while working with a pre-existing unknown disease which is not work related. Expert B has stated that the amount of Worker's Compensation depends on wage amount of the worker, and the percentage calculated upon the inference by doctor consulting the injury.

According to Expert B, Some insurance companies who offer non-life insurances, offers WCI and Contractors' All Risks insurances in a package. Expert B further mentioned that, some insurance companies have WC separated from Contractors' All Risks insurance and each of these systems depends on the requirement of the client. Expert A, discussed that, every person who has completed 18 years can be insured under a life insurance and although a worker has insured under WC insurance or not, he can be insured under a life insurance which a person total insured for the life time towards any hazard. However, Expert A has pointed out that most workers and other civilians have an idea that, life insurance is a waste of money, even though it is a good alternative to the WCI.

4.2. THE WORKERS' AWARENESS ON WORKMEN'S COMPENSATION INSURANCE IN CONSTRUCTION INDUSTRY

4.2.1. QUESTIONNAIRE DATA ANALYSIS

Following Table 3 and Figure 1 presents the awareness and unawareness of workers about Workmen Compensation based on the questionnaire survey.

Table 3: Awareness and Unawareness of Construction Industry Workers about WC

Construction site of contracting Company	Awareness of workers about workmen's compensation	Unawareness of workers about workmen's compensation
Company C	18 (36%)	32 (64%)
Company D	20 (40%)	30 (60%)
Company E	12 (24%)	38 (76%)
Company F	24 (48%)	26 (52%)
Total	**74 (37%)**	**126 (63%)**

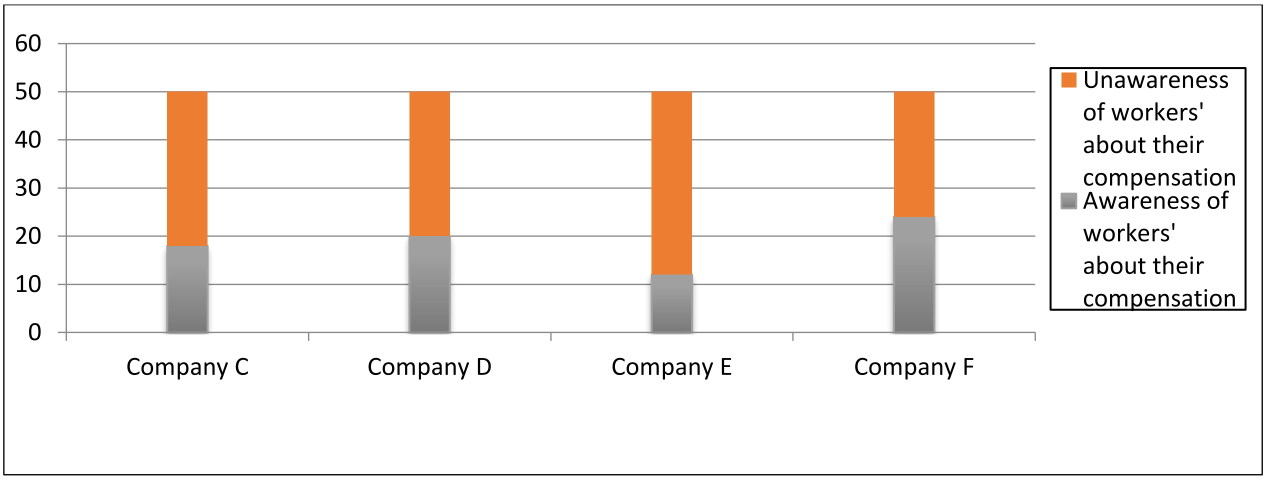

Figure 1: Awareness and Unawareness of Construction Industry Workers about WC

According to the collected data, 37% of workers were aware about WC. Further questions during the questionnaire survey reveled that, 61% of 37% of the workers were aware on the types of injuries which is subjected to compensation correctly, and 29% of 37% stated it incorrect. 63% workers were not aware about WC and most of them had a poor understanding about what sort of injuries will cause to allow them to obtain compensation if an accident occurs during the work at site. 56% of 63% stated that compensation will be paid for any damage that will happen during the working period.

According to the survey, it can be inferred that more than 50% of workers in each site were not aware about the Workmen Compensation (minimum being 52%- Company F). However, Company F has had a seminar about WC in a monthly meeting at site a few months ago; this has resulted in an improvement in the awareness among workers. In other sites, 60% of the workers who were aware of WC mentioned that they became aware of WC from their contractors and safety officers where they have worked before. The other findings of the data has presented in the following Table 4.

Table 4: Other Findings of the Data Collection

Findings		Percentage
The workers in construction sites are changing their contractor very often.		75%
The workers had got injured with common accidents.		70% (140 workers)
1.	Fallings from movable scaffoldings on floors.	15%
2.	Fractures.	10%
3.	Conflict with moving things on the floor or site.	10%
4.	Splitting head or fore head.	10%
5.	Thrashing fingers.	25%
Workers had obtained total compensation for the above mentioned accidents.		15% (21 workers)
The workers didn't receive the total amount of compensation from contractor.		18% (25 workers)
The workers that were not eligible to WC although they met with an accident due to lack of usage of provided safety equipment during the work.		22% (31 workers)

4.2.2. SEMI-STRUCTURED INTERVIEW ANALYSIS

The main aim of this research was to identify the awareness on WC in construction industry. As discussed in the data analysis it showed that 63% of workers were unaware about the Workmen Compensation. According to the view of Expert C, most workers don't have proper interest regarding WC, although government has produced necessary boundaries and systems to secure workers and the insurance parties who mainly involve for the WC process in Sri Lanka. According to Expert E some contractors insure themselves by WCI to cover-up the accidents occurred to his workers during work period while many insure project basis as a requirement of the Employer.

According to the questionnaire data analysis, most of the workers who got injuries while working haven't received compensation. According to the reports of Expert D, usually the reason which the compensation was not paid for the workers is because the WC was not claimed by them, and most of them were minor injuries where the contractor assist in case by case basis. Expert D also mentioned that, the workers are not retaining with one contractor for a longtime duration is the other problem in local construction field. Hence the amount of workforce of contractors is getting waves oftenly, more oftenly the injured workers leaves the site even before the compensation is processed. Expert E also has admitted the above fact and stated that there is a relationship between the Worker turn over and the unawareness of the workers about WC.

Expert C stated that, if a worker was absent due to any injuries for few days uninformed, contractors acts in presumption that the injured worker has left the site and he simply removes those Workmen from his worker list and replace another worker and therefore the injured worker has to bear his injuries himself. Therefore Expert C has discussed that, workers also have to inform and should obtain compensation or claim for his injuries and contractors have to cover up the injured workers compensation. Experts C further discussed that contractors and workers both contribute to this fault continuously due to lack of workers awareness about WC, unawareness of worker's rights, and the extent of contract boundaries with their contractors and so on.

Another fact identified from the analysis is that, 18% of workers had mentioned that some workers have not received the total amount of compensation from the contractor. According to the view of Expert E, this also may be a cause for the workers to change their contractors. Expert E also stated that some contractors use to retain an amount of injured workers compensation with him and pay the balance amount only. This is done by the contractors and the insurance parties as well. Therefore, this is a proof that fault on the part of the contractors and the workers collectively attribute to the non-processing of workman compensation to the desired level.

4.2.3. RECOMMENDATIONS TO MAKE THE WORKERS AWARE OF WC

To make the workers aware of WC, contractors and workers have to fulfill unique and common tasks. According to the findings, the workers in construction sites were having a habit of changing their contractor very often and its 75% amount of labors. According to Expert E this has been a problem for the awareness of the workers about WC and this hinders the necessary steps to be followed to claim WC insurance. The solutions for this matter and the ways of making the workers aware about WC are mentioned in the Table 5 below.

Table 5: Ideas Proposed By the Interviewees to Make the Workers Aware of WC

Interviewee	Opinion
Expert C	▪ That legal procedure has to include how workers join with contractor, how the contractor can eliminate them, the retention amount that contractor keep with him from certain payments, safety of workers, and labor's agreement of compensation and so on. This sort of formal procedures can hardly find in local construction because some construction companies are requesting these documents from selected contractor in the beginning of contract with them. ▪ Modern construction project is a cluster of contractors (suppliers). Among them the labors suppliers are one of main type as the workers are specify for different works. Professionals and safety officers can make those workers aware about the compensation. ▪ The safety officers can include short seminars about worker compensation once in 4 or 5 months into monthly meeting where every worker and every party of the project gather.
Expert D	▪ A recommendation is suite to provide as some contractors aren't paying the total amount of injured worker's owned compensation. One of the reasons why this persists is due to the worker's unawareness of his compensation. To avoid these occurrences the safety officers can come across as an intermediary.
Expert E	▪ Contractor can make the workers aware of workers' compensation and how they will eligible to accept their compensation and main conditions of WC. Each Contractor has to maintain a log of injuries and the workmen compensation claimed as historical data.

5. CONCLUSIONS

Construction industry is one of the sectors having highest fatal injury rates in Sri Lanka which can lead to death of workers with consequent implications for their dependents, or result in injury or disability that may be temporary or permanent, or even get in contact with an occupational diseases. In such occasions, liability of paying WC lies with the Employer according to the WCO, however subjected to exceptions. It was evident that the purpose of WC is to minimize the consequences of aftermath of an incident and the act provides the power to the WC Commissioner to grant permission for Insurance Corporations to grant WCI to indemnify the Employers.

Although WC process is implemented in Sri Lankan construction industry through the WCO, the awareness on WC and WCI among the workers was not satisfactory according to the findings. Casual approach taken by the contractor by not informing the proper procedure of informing the workplace accidents to the workers, many accidents were addressed case by case basis considering them as minor injuries and the frequent turnover of the workers were the underlining reasons for this inference according to the semi structured interview analysis. Finally, lack of awareness of the workers and unfair affairs of the contractors was found to be working in tandem, hindering the proper functioning of WC Scheme. So the co-ordination between workers' rights and contractor's liabilities was found to be essential in this context.

Several recommendations to make the workers aware about compensation were provided by the safety officers. Those recommendations were, safety officers can include seminars about WC into monthly meeting, safety officers can come across as an intermediary to make the WC process a success in the construction industry and also formal procedures requires to be implemented in the construction industry to educate on how workers join with contractor, how the contractor can terminate them, the retention amount that contractor keep with him from certain entitlements, safety of workers, and labor's agreement of compensation etc. Moreover, contractors can keep records on WC to process future situations of the similar type. Also, the government can intervene in regulating the functioning of the WCO in the construction industry through the WC Commissioner.

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ZERO LANDFILL FRAMEWORK FOR APPAREL INDUSTRY SOLID WASTE

K.L.A.K.T. Liyanage* and Nayanthara De Silva

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Apparel industry being one of the key economic players, mass production of textile and apparel take place, resulting in a considerable amount of solid waste generation which ultimately ended up in landfills. Shortfalls in solid waste management has created several issues related to environmental, economic and social and thus it has become a burning issue. Therefore, innovative approaches are timely, needed to overcome this national problem. The Zero landfill concept has been identified as one of the innovative approach. Therefore, this research is focused to study the applicability of the Zero landfill concept to the Sri Lankan Apparel industry. For the study, conceptual framework for zero landfilling was developed and further three case studies were selected for the identification of suitability of the framework for the solid waste management in the apparel industry. Documentary evidences, interviews with experts were carried out to achieve the relevant data. The study revealed that industry generates main types of solid waste, such as, fabric, paper, cardboard, food waste and considerable amount of such waste can be managed through this proposed framework. A considerable amount of plastic and polythene waste ended up in landfills causing difficulties in achieving zero landfill concept for the apparel industry. With the expert opinions, it was confirmed that zero landfill concept can be achieved in the apparel industry by zero landfilling of plastic and polythene waste. Thus, the zero-landfilling concept can be implemented successfully in the country. Further, as landfilling has become a burning issue in the Sri Lankan context, the Zero landfilling concept is a vibrant solution to eliminate the solid waste landfilling.

Keywords: *Adaptability; Apparel Industry; Solid Waste Management; Zero Landfill.*

1. INTRODUCTION

The apparel industry has been one of the fast-growing industry in Sri Lanka, where the rapid generation of solid waste has taken place (Weerakoon et al., 1996). In the textile and apparel world, solid waste is produced at all the points in the manufacturing process (Larney & Aardt, 2010).Solid Waste (SW) is the portable objects that have been abandoned by the owners (Bilitewski et al., 1997). In the textile and apparel industry, major types of solid waste that get generated are, fabric, polythene, paper, plastic, glass, metals and cardboard (Larney & Aardt 2010; Weerakoon et al, 1996).

When disposing of SW, landfilling is the most common waste disposal method throughout the world and landfill is an area of land onto or into which SW is deposited (Fatemi, 2009; Manfredi et al., 2009).In developed countries such as United Kingdom (UK), United Stated of America (USA) nearly 40% to 60% of textile and apparel waste ended up in landfills (Fuchs, 2016).In, developing countries like in China 2.6 million of waste is landfilled while in South Africa, 62.1 % of apparel waste ended up in the landfills (Jordeva et al., 2015; Xue et al., 2014).If this situation continues, the availability of landfills will be decreased while the volume of SW continued to be increased (Domina & Koch, 1997).

At the same time, Bellezza (2003) said dumping of waste to landfill, causes aesthetical problems, health hazards, and environmental problems. Many waste management approaches, including Reduce, Reuse, Recycle (3R), green supply chain, lean manufacturing, and zero landfills have been suggested to overcome these problems (Bowen et al., 2001; Dissanayake & Sinha, 2012; Kaur et al., 2016; Franchetti, 2012).

*Corresponding Author: E-mail – kushiliyanage23@gmail.com

For the disposal of solid waste, huge lands are required. Thus, as per Franchetti (2012), the zero landfill concept has been identified as the most effective strategy to reduce the waste dumping into landfills. Gjetley and Pierre (2003) explained, zero landfill as the operation in which generated waste does not send into the landfill. But the problem here is, there is a lack of studies on the applicability of this concept to Sri Lanka. So this study focuses on how to adapt zero landfill to Sri Lankan apparel industry and to develop a framework for zero landfills using apparel waste along with the objectives to identify the types of waste generated in the apparel industry, to identify the waste management strategies, to study the adaptability of zero landfill concept to the apparel waste and to develop a framework for zero landfill to apparel industry.

2. LITERATURE REVIEW

2.1. *SOLID WASTE IN THE APPAREL AND TEXTILE INDUSTRY*

With the industrial revolution, apparel production has started to bloom. Bailey (1993) has explained the success of the apparel industry was based on mass production of low-cost styles. Hemachandra (2009) has identified apparel producer types as knitted, woven, weaving operators, and fabric producers, washing and dyeing operators. The production process of the apparel industry consists of pre-treatment, bleaching, dyeing, printing, sizing, de-sizing, and mercerization, washing, and finishing (Singh, 2014). Furthermore, Jayasinghe et al. (2010) stated that, annual fabric consumption of apparel and textile sector of Sri Lanka is nearly 19,000 to 38,000.Apparel and textile waste have given a greater concern in both developed and developing countries (Altun, 2012). Apparel and textile waste have categorized as post consumer waste and post industrial waste (Tomovska et al., 2016). Furthermore, Domina and Koch (1997) have identified paper, yard waste, metals, plastic, glass and post consumer textiles as waste types generated in textile and apparel industry. Moreover, Tomovska et al. (2016) have identified textile waste, paper, plastic, reels, and buttons as waste within the apparel and textile industry.

In the Sri Lankan context, fabric, paper, gunny bags, cardboard, and polythene have been identified as the apparel waste (Weerakoon et al., 1996) Similarly, Larney and Aardt (2010) have grouped apparel waste as paper, cardboard, metals, plastic while textile wastes such as fibers, yarn, and cutting waste. Not only that they have also identified that fabric cutting waste, thread waste, notion scraps, waste paper, yarn cones and tubes and packaging waste as apparel waste that are generated in the apparel industry. For the disposal of waste, landfills have been considered as the most common, economical and environmentally accepted method (El-Naqa, 2004). Even though there are different types of approaches used for waste management, a significant amount of waste still ended up in the landfills (El-Naqa, 2004).

2.2. *SOLID WASTE MANAGEMENT STRATEGIES*

The rapid increase in the purchase and disposal of textile and apparel products have resulted in the waste management (Dissanayake & Sinha, 2012). To manage solid waste, institutional regulatory reform and waste reduction technologies are used (Kansal, 2002). Further, Sakai et al. (1996) have stated that, to develop solid waste management strategies, most of the countries follow waste management heirachy which comprises of prevention, material recovery, incineration and landfilling.

2.2.1. 3R CONCEPT

Components of 3R concepts are Reduce, Reuse and Recycle (Aadal et al., 2013). Authors have defined reducing as the method used to decrease the waste production by choosing and utilizing factors. Moreover, they have identified recycling as the step in which waste is used as a resource. Use of the product for the same purpose along with resale and redistribution has defined as reuse (Fletcher, 2008).

2.2.2. GREEN SUPPLY CHAIN

Raj, Ma, Gam, and Banning (2017) defined apparel supply chain as the collaboration of a multiple number of channel members at different levels starting from raw material procurement to the finished good development. Purchase of materials for the organization to enhance environmental outputs by reducing material flow impacts through reuse, recycle, reduction in energy and material wastage have been defined as the green supply chain (Bowen et al., 2001).

2.2.3. LEAN MANUFACTURING

A lean manufacturing adaptation of the organization involves with cultural change, higher profits, and higher employee commitment (Kaur et al., 2016). The authors have explained when adapting lean to the textile and apparel industry, Key Performance Indicators (KPI), current activity measurement, improvement of figures have been considered. Through lean manufacturing, customers are supplied with the exact amount that is needed for them without creating any waste (Ali, 2012). Furthermore, Ali (2012) stated that, for the lean production, Just in Time (JIT) have contributed. When an organization adopts lean manufacturing strategy, employees can inspect their own products and can minimize the delivery of defect products (Chiromo et al., 2015).

2.2.4. EXTENDED PRODUCER RESPONSIBILITY

Extended Producer Responsibility (EPR) is another strategy that is being used in the process of recycling (Chavan, 2014). The author has said that through the EPR, the manufacturer is responsible for the entire life cycle of the product, where the manufacturer is liable for the take-back, recycle and final disposal. To reduce and to avoid major waste volumes during the production process of the product, EPR is an important tool (Lindhqvist, 2000). In order to encourage cleaner production process and to eliminate waste during the different stages of the product life cycle EPR has to be followed (Fatemi, 2009).

2.2.5. ZERO LANDFILLS

The operation in which generated waste does not send into the landfill is identified as the zero landfill (Gjetley & Pierre, 2003). Furthermore, Lombardi (2011) has identified zero landfills as the redesigning of the resource life cycle where no resource gets wasted to the landfill throughout the process. The excessive generation of wastes and the overuse of land for landfills create an increasing environmental burden for the society which causes more optimal use of land (Tan & Khoo, 2006). Therefore, by achieving zero landfill, it would help to overcome the harmful effects that take place due to waste dumping into the landfills.

2.3. BENEFITS OF ZERO LANDFILL

Waste dumping in landfills have led to the harmful effects of environment, land, air, and water (Gjetley & Pierre, 2003). Therefore, the authors have stated that achieving zero landfill would help to overcome the harmful effects that take place due to waste dumping into the landfills. Benefits of Zero Landfill concept can be discussed under ecological and economic benefits.

- **Ecological benefits**

Bartl and Haner (2009) have said that, more ecological benefits can be achieved with the improvement in fiber recycling technologies which have impacted on the higher recovery rate. For the ecological textile and apparel production, environmental demands have made a huge impact (Domina & Koch, 1997). Authors have further explained that, instead of waste disposal to landfills, apparel manufacturers are looking into number of recycling alternatives. Kavitha and Manimekalai (2014) have stated that, issues that can arise as a result of waste dumping to the landfills, can be reduced by avoiding synthetic product dumping in the landfills and by reducing the pressure on virgin resources. Through different alternatives such as, involvement of government, environmental policies, and awareness through media, waste dumping in the landfills can be controlled (Domina & Koch, 1997).

- **Economic benefits**

In order to achieve zero landfills, textile and apparel manufacturers have looked into alternative recycling methods. As a result of the improvement in fiber recycling technologies, economic benefits can be achieved (Bartl & Haner, 2009). Domina and Koch (1997) have said that, waste disposal to landfills is an inexpensive, easy method in which less commitment has to be paid for recycling programs. Authors have explained that, for products like paper, glass and aluminium cans recycling efforts are taken as it has a resale value.

3. RESEARCH METHOD

To identify the adaptability of Zero landfills to apparel waste, expert's attitude and experience have to be considered. Therefore, the qualitative approach is used for the study. Bloor and Wood (2006) stated that in-depth analysis and detailed understanding can be achieved through the case study. Hence,in order to identify the adaptability of Zero landfill concept to the apparel industry more cases needed to be studied. Therefore, for the study three cases were selected from the top three key players in the apparel industry where waste management practices are being followed to reduce waste generation.Selected factories are namedas case A, case B, and case C those who are into export of apparel products. Table 1 shows the details of the cases.

Table 1: Profile of the Cases

Criteria	Case A	Case B	Case C
Production category	Casual wear garments	Sample sportswear	Lingerie garment products
Production capacity (garments per month)	250000	1000	40000
Work force (Person)	3000	520	750
Respondent	Senior Maintenance Manager (A1)	Senior Executive Sustainable Engineer (B1)	Senior Executive Sustainability (C1)
Years of experience in the field of WM	4 ½ years	3 ½ years	1 ½ years

Data collection was carried out through semi structured interviews, document review and through observation to identify the types of solid waste, their management process and further expert personnel in the field of waste management were interviewed to identify the applicability of the zero landfill concept to the apparel industry. Moreover, to validate the proposed framework and collected data, five expert personnel were interviewed. Table 2 shows the profile of the interviewed experts to validate the proposed framework.

Table 2: Profile of the Experts

Respondent	Description	Experience
E1	Managing Director of Plas Techs (Pvt) Ltd	25 years
E2	Deputy General Manager in Compliance and Sustainability	10 ½ years
E3	Deputy Project director of construction of SW disposal facilities project in Central Environmental Authority (CEA)	30 years
E4	Director of Western Province Waste Management Authority	25 years
E5	Director of Environmental Division of Katunayake BOI zone	25years

Proposed conceptual framework to find the applicability of zero landfill concept to the apparel industry is shown in Figure 1.

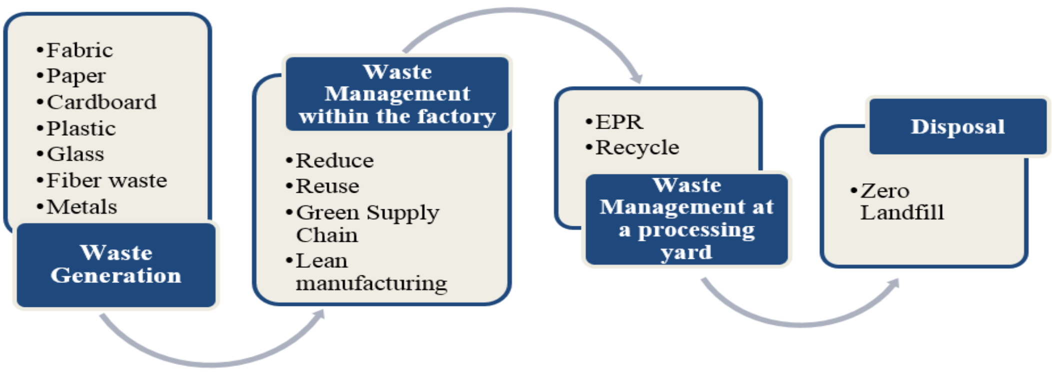

Figure 1: Conceptual Framework

4. RESEARCH FINDINGS AND ANALYSIS

The study of adaptability of zero landfill for Sri Lankan apparel industry had in depth study as this is a novel area for Sri Lanka. To achieve the ultimate aim of the study, three (03) case studies and five (05) expert interviews were carried out.

4.1. TYPES OF WASTE

Although SW types like fabric, paper, cardboard, plastic, glass, fiber and metal were identified as the textile and apparel waste types through literature findings, according to the case study findings, major types of SW that can be found in Sri Lankan textile and apparel industry are fabric, polythene, plastic, paper, cardboard and food. In all three cases, these SW waste types were identified. Quantities of waste in each case by weight for the year 2016 are shown in Table 3.

Table 3: Types of Waste and their Quantities

Type of waste	**Waste by weight (in Kg/ per year)**		
	Case A	**Case B**	**Case C**
Fabric	70000	15473.19	22679.6
Cotton Fabric	5000	-	-
Paper	7500	12827.45	2723.55
Cardboard	18000	4904.50	9628.74
Plastic/Polythene	3407.85	2981.61	1769.01
Food	30000	11302.05	21563.24
Glass	Very small quantity	Very small quantity	Very small quantity
Metals	Very small quantity	Very small quantity	Very small quantity
Sanitary waste	Very small quantity	Very small quantity	Very small quantity

4.2. WASTE MANAGEMENT PROCESS

In the apparel industry, once the SW gets generated, firstly, point wise waste segregation takes place. Depending on the nature of the SW type, SW are separated. Then those segregated SW are placed in the waste storage yards. From the waste storage yards, waste collectors collect SW for reuse and recycling purposes. Finally, through the waste collectors, residual SW those are unable to reuse or recycle, are disposed to landfills.

SW that are generated through the factories are, fabric, cotton waste paper, cardboard, plastic, polythene, food, glass, metals and sanitary waste. To handle waste within the factories, rather than the waste management procedure, colour coding bin arrangement system and 3R concept are being followed. When it comes to the colour code bin arrangement system, for the disposal of food waste, green colour bins are used while plastic and polythene are sorted into orange colour waste bins. Blue colour waste bins are used to collect paper and cardboard waste. For the waste collection, waste collection yards are available and they are divided as SW and hazardous waste. All the food waste are sent to a piggery farm on a daily basis. Once the waste gets collected in the waste yard, they are taken by the separate waste collectors. Factories that are within the Board Of Investment (BOI) zone, waste get collected in the BOI waste yard and from the waste yard, waste recyclers collect the waste. Separate waste collectors are available to collect plastic, polythene, fabric, cardboard and paper waste. After the recycling of SW, if there are any residuals, those residuals are discarded into landfills.

4.3. WASTE MANAGEMENT STRATEGIES TO SW HANDLING

To handle the SW generated within the factory, it was observed that different approaches are followed by the factories. In each case, waste management approaches like reduce, reuse, green supply chain, lean manufacturing are used to handle waste.

4.3.1. REDUCE

When considering about all 3 cases, different approaches have been followed to reduce the SW in each factory. Table 4 shows the reduce approaches used by apparel factories.

Table 4: Reduce Approaches in Factories

SW approach	Case A	Case B	Case C
Both side of the paper used for documentation activities	√	√	√
Elimination of PET water bottles	√	√	√
Use of poly bags	√		
Use of plastic tags	√		
Use of fabric bags to transport finish products	√		
"N-CING" computer aided method for production floor which helps for paperless production		√	
"View sticker", a 3D technique to check on samples		√	
Using email memos instead of leaving notes			√
Suppliers are asked to use less packaging			√

4.3.2. REUSE

Reuse of SW is another approach that helps to achieve zero landfilling in the long run. Apparel factories follow strategies shown in Table 5.

Table 5: Reuse Approaches in Factories

Approach	Case A	Case B	Case C
Use of water dispensers and glass water bottles	√	√	√
Fabric off cuts are used for handloom productions	√	√	√
Reusing of thread cones after rewinding		√	√
Reuse of cardboard boxes	√		
Paper used in sublimation printing are used in cutting section		√	
Paper in cutting section are used to prepare envelop		√	
Remaining trims in the production floor is collected by the stores and reused		√	
Fabric waste are reused as kitchen napkins and hand wipes in kitchen areas			√

4.3.3. GREEN SUPPLY CHAIN

While purchasing materials, environmental concerns can be seen. From the findings related to the three cases, it can be seen that the partnerships are made with the manufacturers those who are into sustainable approaches. Moreover, for the production of garments, organic cotton are being used. Organic cotton is the type of cotton in which chemicals are not being used during the manufacturing process. In order to minimize and to improve the productivity within the supply chain, cleaner production techniques are being used to facilitate the environmental performance of the industry. Cleaner production is the strategy that is used to reduce the impact of production on the environment by preventing at the source. Cleaner production techniques such as transformation of waste into useful products, reverse logistics, waste segregation have resulted in using environmental friendly technologies within the factory. Green productivity is considered to enhance the productivity and environmental performance.

4.3.4. LEAN MANUFACTURING

With the focus on waste reduction and non-value adding activities within the factory, lean manufacturing can be implemented. In all three cases, for the lean manufacturing practices, value stream mapping, marker efficiency for fabric cutting and lean manufacturing tools such as 5S, Just In Time (JIT) Kanban are followed within the factory. Excessive production of garments and waste generation have reduced as a result of lean manufacturing. In order to reduce fabric waste, design changes are carried out by discussing with the designers.

If the designed garment has curves which leads to wastages of fabric, after discussing with the designers, in order to minimize the damages, curves are turned into sharp edges. Complimentary products such as hair bands and hand bands are produced from the fabric off cuts.

4.4. WASTE MANAGEMENT APPROACHES TO TRANSFER WASTE

By using waste management approaches like reduce, reuse, green supply chain and lean manufacturing, SW can be managed to a certain extent. But those approaches cannot avoid SW ends up in the landfills. Therefore, to avoid SW ends in landfills, waste management approaches like EPR and recycle can be used.

4.4.1. EXTENDED PRODUCER RESPONSIBILITY (EPR)

When the producer take the responsibility for what he produce, then it helps to reduce the waste generation at the end as well as during the production of the product. Producers take the responsibility of the product by taking back their garment products at the end of the useful life. When the life cycle of the product is designed from the initial stage, it helps to reduce the waste at the end disposal.

4.4.2. RECYCLING

For the recycling of waste within the factory, factories have joined with 3rd parties those who have a license to do the recycling activities. To recycle fabric, paper, cardboard, plastic and paper there are separate waste collectors in each factory. For the recycling of plastic, paper, polythene and cardboard, 3rd party recyclers are registered under the Central Environment Authority (CEA).

4.5. WASTE DISPOSAL

From the findings, after following the waste management strategies, portion of waste get ended up in the landfills. Table 6 shows the weights of waste ending up in landfills.

Table 6: Weights of Waste Disposed to Landfills

Waste Type	Waste disposal from factory to the waste collectors (kg/per year)			Waste disposal to landfills from the waste collectors (kg/per year)		
	Case A	Case B	Case C	Case A	Case B	Case C
Fabric	70000	15473.19	70000	0	0	0
Cotton Fabric	5000	-	-	0	-	-
Paper	7500	12827.45	2723.55	0	0	0
Cardboard	18000	4904.50	9628.74	0	0	0
Plastic/Polythene	3407.85	2981.61	1769.01	165.35	125.24	65.28
Food	30000	11302.05	21563.24	0	0	0

According to the findings from the three cases, it can be observed that landfilling of waste take place only from plastic and polythene. Disposed SW in the factory is equal to the generated waste in the factory. It is because the generated waste is given to the waste collectors to reuse or recycling purposes. Waste collectors convert fabric waste into energy through waste recovery. Therefore, fabric waste does not end up in the landfills. Paper and cardboard waste that is generated in factories are recycled and paper and cardboard produced again. Hence, paper and cardboard waste also does not end up in the landfills. Food waste is sent to a piggery farm as food for pigs. Hence, it is clear that, fabric, paper, cardboard and food waste does not end in landfills. As per the findings of the case study, it is observed that portion of plastic and polythene waste end up in landfills and it is shown in Table 7.

Table 7: Weights of Polythene and Plastic Waste Disposed to Landfills

Case	Quantities of Plastic and Polythene waste		Waste disposal percentage to the landfill (%)
	Waste at generation (Kg/per year)	Waste sent to landfills (Kg/per year)	
Case A	3407.85	165.35	5
Case B	2981.61	125.24	4
Case C	1769.01	65.28	4
Total	8158.47	355.87	4

As per the findings, it was evident that 4% of polythene and plastic waste get ended up in the landfills. Main reason for this 4% of plastic and polythene waste landfilling is due to the difficulties in proper point wise segregation, high recycling cost, inadequacy of proper technology for recycling, lack of recycling capabilities of recyclers, food waste remains on lunch sheets, remaining polythene and plastic waste are not be compatible with the recycling purposes and poor planning of product life cycle. Experts stated that, zero landfill concept can be achieved by eliminating 4-5% of polythene and plastic waste. In order to eliminate the plastic and polythene ending up in landfills, their views were to follow proper waste hierarchy, proper point waste segregation, proper monitoring system to 3rd party vendors, maintain direct agreements with end disposer, use of new technology like pyrolysis, segregation of polythene waste according to the thicknesses and awareness on not to produce with mix polymers. Hence, it can be concluded that, zero landfill concept can be adapted to the Sri Lankan apparel industry. All the research findings were harmonised into one place and framework was developed to achieve zero landfill as shown in Figure 2.

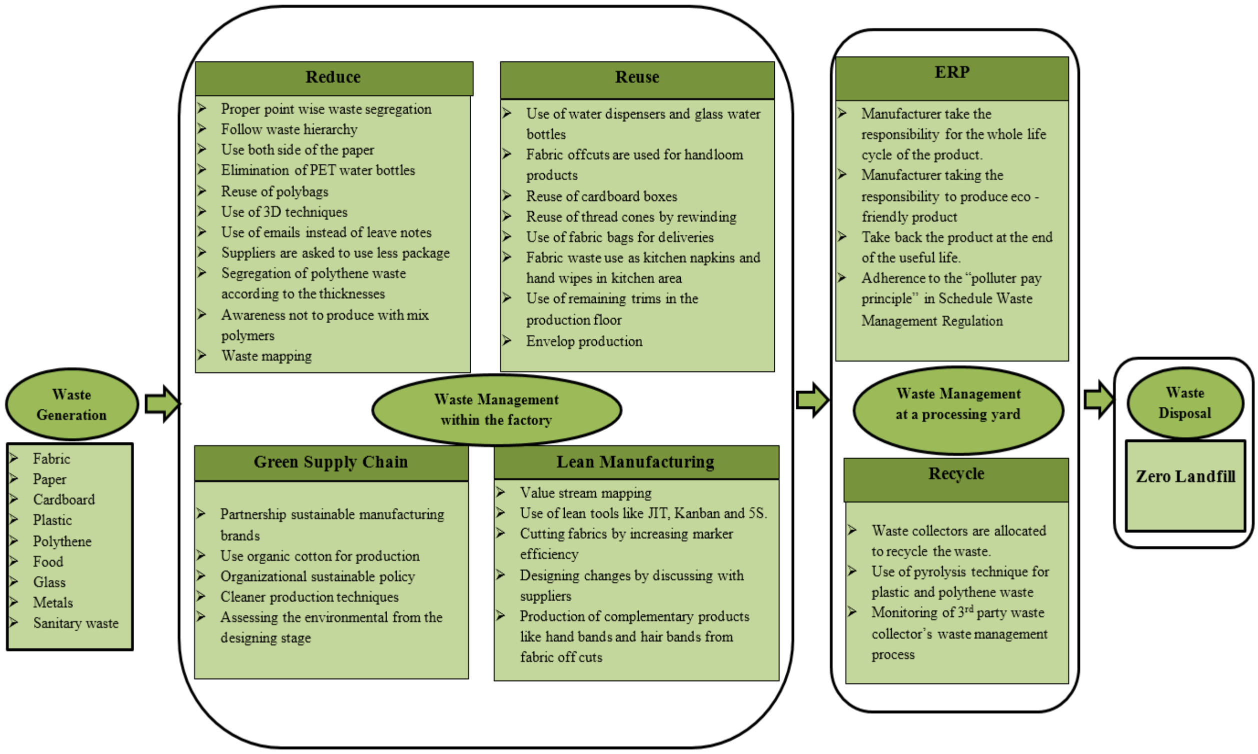

Figure 2: Framework for Zero Landfill of Apparel Waste

5. CONCLUSIONS

Apparel industry, being one of the key economic contributor with large scale textile production considerable amount of waste gets generated through the industry which ultimately end up in the landfills. Therefore, the applicability of the zero landfill concept to the apparel sector was the focus of the study. In apparel industry, types of solid waste generated are identified as fabric, cotton fabric, paper, cardboard, plastic, polythene, glass, metals, and sanitary waste. Waste management strategies like lean manufacturing, Extended Producer Responsibility (EPR), green supply chain, 3R concept can be followed to achieve zero landfill concept. The process in which the generated waste does not send into the landfill can be defined as zero landfilling. Through the study it was observed that, for the solid waste management in the factories, point wise waste segregation, follow up of the waste hierarchy, use of both sides of the paper for documentation activities, PET water bottle elimination, use of fabric off cuts for handloom production, partnerships are made with sustainable manufacturers, and use of organic cottons for productions is being followed. By following up these practices, it was observed that solid waste types like fabric, paper, cardboard, food achieve the zero landfilling while nearly 4-5% of plastic and polythene waste get ended up in the landfills. With the expert opinion, it was confirmed that 4-5% of plastic and polythene waste too can be zero landfill. Therefore, by following up this framework, zero landfilling can be achieved. With the case study findings and expert interviews, adaptability of zero landfill concept to the apparel waste was accomplished. Finally, a framework was developed to elaborate the adaptability of zero landfill concept to the apparel industry.

6. LIMITATIONS AND PRACTICAL IMPLICATIONS

The research is limited to the factories in the western province. Moreover, there were difficulties in collecting data as the concept is novel in the Sri Lankan context. Further, the applicability of the concept is confirmed purely through expert views and there may be practical issues when implementing the concept into the practical scenario.

By implementing this concept, it will help to overcome from the social, environmental and health issues that arose as a result of waste dumping into landfills. Furthermore, waste authorities can use this as a positive study to find solutions for the solid waste landfilling issue. Based on the findings, authorities can look into adequate infrastructure to facilitate the proposed methods in an effective way.

7. RECOMMENDATIONS

As recommendations for industry practitioners, it is necessary to implement proper point wise segregation and awareness need to be given to employees on the importance of point wise segregation. Moreover, management commitment needs to be enhanced and strategies need to be formed to reduce waste generation in the apparel industry. Further, direct relationship with end disposer need to be maintain and end disposal activities need to be evaluated.

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Ceylon Institute of Builders

No.4-1/2, Bambalapitiya Drive, Colombo 04.

Tel : +94 (0) 113 140355 , +94 (0) 112 508139 | E : info@ciob.lk

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