THE 6th WORLD CONSTRUCTION SYMPOSIUM – 2017

SYMPOSIUM PROCEEDINGS

30th June - 2nd July 2017

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COLOMBO

The 6th World Construction Symposium

What's New and What's Next in the Built Environment Sustainability Agenda?

The 4th Green Building Awards Ceremony

ORGANIZED BY

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DEPARTMENT OF BUILDING ECONOMICS
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THE 6TH WORLD CONSTRUCTION SYMPOSIUM 2017

THEME

WHAT'S NEW AND WHAT'S NEXT IN THE BUILT ENVIRONMENT SUSTAINABILITY AGENDA?

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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 speakers, 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 moderator of panel discussion on "*The Good, the Bad and the Optimal: Greening Potential, Grey Areas and Life-Cycle Best Value*". The Faculty of Graduate Studies, University of Moratuwa is also acknowledged with a greater gratitude for sponsoring keynote speaker under the grant scheme on "*Funding for International Conferences and Symposia 2017*". We are also thankful for the other organisations that have provided sponsorships.

Last but not least, all our colleagues in the organising committee and symposium secretariat are especially thanked for devoting their time and effort to make 'The 6th World Construction Symposium 2017' a success.

Editors

The 6th World Construction Symposium 2017

Colombo, Sri Lanka

July 2017

PREFACE

The 6th 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 on 30 June - 2 July 2017 in Colombo with the partnerships of Liverpool John Moores University, United Kingdom, Centre for Innovation in Construction and Infrastructure Development (CICID), The University of Hong Kong, Indian Institute of Technology Madras (IIT Madras), Northumbria University, United Kingdom, Robert Gordon University, United Kingdom, Western Sydney University, Australia, CIB-W122: Public Private Partnerships and Colombo School of Construction Technology (CSCT), Sri Lanka 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 "What's New and What's Next in the Built Environment Sustainability Agenda?

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, PPPs for a Sustainable Built Environment, Public Private Partnerships (PPPs) and Green Innovation, 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, 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, 54 papers were selected for publication, covering eight countries, i.e. Sri Lanka, India, United Kingdom, Australia, Hong Kong, Malaysia, Turkey, 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 in sustainable development in Built Environment.

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Prof. Akintola was previously Director of Research and Innovation of Faculty of Science and Technology and Dean of Grenfell-Baines School of Architecture, Construction and Environment at the University of Central Lancashire, United Kingdom. He holds the Chair of Construction Economics and Management. He was Visiting Professor to the Department of Civil Engineering, Asian Institute of Technology, Thailand and the Department of Building and Real Estate, Hong Kong Polytechnic University and a Distinguished Scholar of the University of Cape Town, South Africa. He is Fellow of both the Royal Institution of Chartered Surveyors and Chartered Institute of Building and Past Chair of the Association of Researchers in Construction Management. In addition, he is Editor-in-Chief of the Journal of Financial Management of Property and Construction. Professor Akintoye is Co-Coordinator of the World CIB Working Commission (W122) into Public Private Partnership.

He has gained international recognition for his scholarly work in the area of construction risk management and procurement, construction estimating and modelling, construction economics, and construction inventory management. He has over 150 academic publications and outputs and has been invited as keynote speaker to conferences in USA, Europe, Asia, Australia and Africa.

Professor Akintoye has continued to work very closely with industry in the UK and have established a robust international network of experts in many countries. He has served in various consultancy teams which have advised government institutions and private organisations on PPPs and PFIs across Europe and Asia. He has edited four published books in Construction Innovation and Process Improvement and Public Private Partnerships.

Prof. Srinath Perera

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Professor Srinath Perera is a coordinator of the CIB TG83 Task Group, e-Business in Construction. He has been admitted as a Fellow of the prestigious Royal Society of New South Wales and is a fellow of the Australian Institute of Building (AIB). He is a Chartered Quantity Surveyor and a Project Manager with membership of both the Royal Institution of Chartered Surveyors (RICS), and Australian Institute of Quantity Surveyors (AIQS). He has worked as a consultant quantity surveyor, project manager and as an academic in Sri Lanka, Ireland, UK and Australia.

He has extensive experience in doctoral student supervisions and examinations. He has over 150 peer reviewed publications and is co-author of the popular textbook Cost Studies of Buildings 6th edition, published by Routledge.

He has successfully supervised and examined several doctoral and higher degree candidates around the globe. He has extensive experience as external examiner for several undergraduate and postgraduate degree programmes in many universities. He has also served in several course accreditation and validation panels for various universities and professional bodies both within UK and internationally.

CONTENTS OF PAPERS

A SITUATIONAL PARADIGM ON FLOODING AND BUILT ENVIRONMENT INTERVENTIONS IN THE UK

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ABSTRACT

Flooding in the United Kingdom (UK) is increasing in both frequency and severity, leading to huge social and economic cost consequences, despite which there seems to be limited data or research on built environment related interventions such as effectiveness of flood defence schemes across the UK. As the UK remains at the pinnacle of urban development, this study seeks to underline the inherent relationship between flooding occurrences and the construction industry related interventions. The study examined the effectiveness of flood defences in the UK, regarding their economic suitability, their physical effectiveness and how they are managed and funded by the UK Government. Case study research strategy was employed and interview was used as the data collection method in the case study. This study revealed that the underlying cause of increased flooding in the UK is due to several factors including; climate change and urbanisation. In terms of the physical defences built to protect the built environment, the study has shed light on the level of protection they offer, their cost effectiveness and how such schemes are financed. This study targeted the creation of a situational paradigm that could be transposed and generalised to enhance the understanding of flooding intervention in the UK and other urban environments.

Keywords: *Built Environment; Defences; Disaster; Flood; Leeds; Paradigm.*

1. INTRODUCTION

Natural disasters can cause far reaching damage with the effects from one single event reverberating around the globe through loss of life and property and with economic side effects such as reduced trade and manufacturing, causing even wider disruptions (Ofori, 2004). The IME (2013) states that with 55% of the world's GDP and 44% of trade, and Asia and Pacific forms the powerhouse of the global economy today. It is therefore evident that natural disasters could have a detrimental effect on the global economy and world trade. Leinster (2009) submitted that flooding is a common hazard in the United Kingdom (UK) and has caused significant economic losses. Climate change has been projected to lead to an increase in riverine flooding across the whole of Europe (Kundzewicz *et al*., 2010) and therefore, an increase in damage and losses is likely in the future. A 40% increase in the number of weather related natural disasters since 1980 can be attributed to climate change (Global Humanitarian Forum, 2009). This view is supported by Neumayer and Barthel (2011) and Pielke *et al.* (2008) as the studies submitted that climate change, the rise in living standard, a general increase in population, growth in asset and people concentration in urban areas, industrialisation of risk-prone areas (e.g. coastlines and fluvial plains) are leading to an increase in disaster frequency and cost. Similarly, vulnerability to disasters is increasing due to reasons such as growing population, climate change and other underlying development issues (Wuthisuthimethawee, 2016). Theory on the current global situation has been proposed by several sources such as the Intergovernmental Panel on Climate Change (IPCC) that the impact of global climate change is increasing the frequency of natural disasters both now and in the future (Solomon *et al.*, 2007; Munich Re, 2003).

Flooding in the UK is increasing in both frequency and severity, leading to a huge social and economic cost consequences. Since much of the physical damage brought about by disasters is to structures and infrastructure (Ofori, 2004), the construction industry and the built environment professionals have a vital role to play

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(Malalgoda *et al.,* 2010; Ofori, 2004). As a result, there have been built environment-related interventions. Despite, there seems to be very little data or research surrounding the effectiveness of this interventions and especially flood defence schemes across the UK from the perspective of a built environment professional. Based on the aforementioned, the aim of this study is to analyse the effectiveness of flood defences in the UK, with regards to their economic suitability, their physical effectiveness and how they are managed and funded by the UK Government. This study presents the formation of a pattern consisting of the attributing factors of intra-urban flooding, this will culminate in the creation of 'Leeds paradigm model'. The Leeds model is a situational paradigm which will take the knowledge gained from data collected from stakeholders and literature to explain the interrelationship of factors and other situations. This will form the basis of a generalizable model of factors influencing intra-urban flooding, solutions to intra urban flooding, and an outline of the critical success factors of urban flood schemes.

2. LITERATURE REVIEW

2.1. FLOODING IN THE UNITED KINGDOM

The frequency and severity of flooding is predicted to increase in the UK (ABI, 2007; Soetanto *et al.,* 2008). Foresight Report (2003) commissioned by the Office of Science and Technology, United Kingdom concluded that an increasing flood risk was evident because of climate change affecting the seasonal rainfall patterns. In the same vein, Lamond *et al.,* (2012) concluded that between now and 2080 annual rainfall could increase by as much as 40%.The increased prevalence of natural disasters cannot be solely attributed to climate change or natural factors, a human element of the increase concerns how the built environment manages the whole project life cycle, across all sectors including residential, commercial and infrastructure (Soentanto *et al.,* 2008). For example, high up the River Thames, along non-tidal stretches there are an estimated 12,000 residential properties with an estimated value upward of £1Billion (McGlade, 2002). Flooding in these areas would be labelled as a 'natural disaster' whereas more evidently it is the combined increase of urban development in flood susceptible locations (Bosher, 2008).

In the UK, the continued prevalence of flooding occurrences has been attributed to the decrease in river dredging during the last decade. Stewart Agnew MEP (2014) placed the responsibility for this reduction on the decision to dissolve/integrate the National Rivers Authority into the remit of the Environment Agency (EA), who subsequently placed a large proportion of UK Rivers under the EU Habitat Directive, protecting them from dredging among other processes. The Royal Society for the Protection of Birds (RSPB) have highlighted their opposition to these methods due to the negative affect it has on the natural environment, particularly in the case of the 2013 flooding seen on the Somerset levels they opposed the notion that dredging alone would mitigate the flood risk in this area (Harper and Bowern 2014). Wheater and Evans (2009) provided a summary of driver groups for fluvial and intra-urban flooding, this includes climate change, catchment run-off, groundwater system and processes, fluvial system and processes, urban system processes, coastal processes, human behaviour and socio-economics. The specific drivers in the driver groups include precipitation, temperature, sea-level rise, rural land management, environmental regulation, river morphology, vegetation and conveyance, blockage, external flooding, asset deterioration, coastal morphology, stakeholder behaviour among others.

2.2. FLOODING AND BUILT ENVIRONMENT INTERVENTIONS

Ofori (2003) submitted that "the built environment bears the brunt of damage from disasters of all kinds". Subsequently, Bosher (2008) called for the construction sector to take greater responsibility for the planning, design, construction and maintenance of the built environment. In the same vein, Ingirige *et al.* (2008) identified the construction industry and built environment disciplines as having a primary role in reducing the risk of flooding. The built environment professionals need to be engaged further as a resource for delivering built environment interventions (Bosher *et al.,* 2007). Currently in the UK, more than 5 million homes and over 300,000 businesses are currently at risk of flooding (RICS, 2015). Recent widespread flooding across the UK has once again exposed the vulnerability of the built environment towards flooding. About £1.1 billion is estimated as the current annual cost of flood damages in the UK, with around 1 in 6 properties exposed to some level of flood risk (Blackmore, 2015). The figures published by the Association of British Insurers show a 200% increase in the cost of flood damages since the 1990s (Shrubsole, 2008).

The Stern (2007) was undertaken to investigate the economic impact of climate change. The review concluded that the financial effects of flooding in the United Kingdom was severely underestimated; the current estimate of£1 billion increasing to around £27 billion by 2100. In conclusion, they reiterated that this could only be avoided by extensive financial investment. Several human and anthropogenic factors in the UK have led to several flood events over the past decades. Carlisle is situated on a flood plain, which coupled with ineffective efforts of restricting development in this vulnerable area contributed to the widespread damage caused by the 2005 floods (Bosher, 2008). Towards mitigating the impact of disasters, the Department for Environment, Food and Rural Affairs (DEFRA), United Kingdom expended sums ranging from £500 - £670m annually on flood defences in cash terms from 2007/08 to 2014/15 (Bennet *et al.*, 2014). Apart from expenses on flood defences, the government also spend on the repair of affected communities (Shrubsole, 2015). In 2014, the UK government announced a drop in flood defence funding from £2.37Billion (2005-2010) to £2.34Billion (2010-2015) (Shrubsole, 2015).

There are approximately 80,000 homes across the UK at risk of ‘intra urban’ flooding; the annual flood management costs associated with these areas is over £320 million (Government Office for Science, 2011). ‘Intra urban’ flooding is a growing global problem due to the rapid increase of urbanisation in the 21st century. In 2010 the global average of the urbanised population passed the 50% mark (IME, 2013). ‘Intra urban’ flooding is a symptom of an inadequate water system that is failing to accommodate ever increasing flood levels, the urban water system comprises of a combination of the above ground surfaces and the water service infrastructure (Thorne *et al*., 2007). Urban creep is another product of increased urbanisation; this is the process of increasing the impervious area, through small and large scale urban developments (Thorne *et al*., 2007) this factor exacerbates pluvial flood risk. Right now, fluvial and pluvial flooding is a growing problem in the urban environment.

One of the methods for combatting the effects of intra urban flooding is to introduce a sustainable urban drainage system (SUDS). This technique is an integrated alleviation system that encompasses all facets of the urban environment; it seeks to treat water in a different way to conventional drainage (Thorne *et al*., 2007). Lamond *et al.* (2012) state that the benefits of using this technique for flood attenuation are both clear and “unequivocal”. There are several individual drainage devices that can be used in a SUDS system. The four main classifications are as follows: filter strips, permeable surfaces, infiltration devices and detention services (Lamond *et al.,* 2012). Lamond *et al.* (2012) also listed some vegetative devices (rain gardens, wetlands, swales, household rain gardens, filter strips) and hard devices (porous paving, concrete rain garden, rainwater harvesting, front gardens and school playing fields). The implementation and construction of a SUDS scheme can change in both scope and definition depending on whether retrofitting the system into the existing built environment or integrating it into a new build scheme (Lamond *et al.*, 2012). Currently in the UK hard drainage infrastructure is designed to deal with a 1:30 year storm (Thorne *et al*., 2007). Considering the evidence pointing towards an increase in intense rainfall events, peak river flows and rising sea levels, most would consider this inadequate.

3. RESEARCH METHOD

Qualitative research allows for a greater understanding of participants' experiences, determining the significance of variables through their discovery and discussion (Corbin and Strauss, 2008). In this study, case study research strategy was employed because it is effective in research to support claims being made and draw conclusions. Case studies can be undertaken with regards to individuals, organisations and groups, and for this research the case study focused predominantly on a flood defence construction project, the Leeds Flood Alleviation Scheme (LFAS). This case study is one of the most significant built environment-related flood interventions in the UK, it was purposively selected based on its potential revelatory attribute. This study specifically focused on LFAS project costs, cost benefits, the financing of the project and the effectiveness of the flood protection the scheme offers to establish a situational pattern of flood defences. Primary data was collected using four in-depth semi-structured interviews with management and construction professionals involved in LFAS. Table 1 outlines the profiles of the interviewees. The data facilitated creating a situational paradigm outlining the cause and effect of ‘intra urban’ flooding - The case of Leeds with the expectation of enhancing the understanding of the growing problem across major UK urban areas. The interviews were further used to corroborate both the secondary and primary data acting as a method of triangulation to create the situational paradigm.

Table 1: Profile of Interviewees

Interviewee	Position	Experience (Years)
A	Project Manager	17
B	Civil Engineer	11
C	Quantity Surveyor	7
D	Project Manager	4

4. LEEDS FLOOD ALLEVIATION SCHEME (LFAS)

Before the turn of the century, Leeds was not regarded as an area that presented a high risk of flooding. However, flooding over recent years has highlighted a growing problem in the area. The city of Leeds is situated on the River Aire which contributes to pluvial flooding; compounding this is the risk of fluvial flooding due to the unsuitable drainage and increased urbanisation. Over the past decade, upon the need for defences was highlighted, various schemes have been proposed and rejected due to several factors including financial constraints and community intervention. Finally, in 2012, the business case was passed for the development of the LFAS. A £45million investment was funded by a new model of public funding. The system encompasses several existing defence technologies and innovative system.

5. DATA ANALYSIS AND RESULTS

Since qualitative analysis builds on natural ways of thinking, interviews were conducted and the responses were coded using the thematical method. Thereafter, the themes were used to build a common understanding of the response; thus, allowing the formation of concepts. Specifically, the interviews provided the theoretical ‘themes’ that outlined the relationship between the research variables. This analysis provided a detailed set of situational concepts which were used to form the situational paradigm. The creation of the situational paradigm consists of ‘case’ specific patterns obtained from the triangulation of both secondary data/literature and case study interviews.

Presented below are the findings from the interviews. The themes were aligned with associated discussions in the literature towards the creation of a situational paradigm.

5.1. DRIVING FACTORS FOR INCREASED FLOODING FREQUENCY AND SEVERITY

Three of the four interviewees highlighted climate change as a driver of increasing flooding frequency and severity in the UK, with interviewee stating *“climate change is a primary driver”*. Primarily interviewees A and D mentioned the changing climate is resulting in more *“frequent heavy storms”* and *“severe, warmer and wetter weather”*. These views are shared by Soentanto *et al.* (2008) and by the Foresight Report (2003) who link climate change to increasing severe weather patterns. Another factor that ranked just as highly as climate change was unsustainable development. This theme consists of many individual points from interviewee A stating that *“a period of increased building in the environment”* to interviewees B and C highlighting the *“property development low within a flood plain”* and *“development of greenfield sites”*. The views of unsustainable development as an attributing factor are advocated by Mc Glade (2002). Urbanisation has been identified throughout the secondary research as a driving factor in flooding severity (Bosher, 2008; Thorne *et al.,* 2007; Wheater and Evans, 2009). Interviewee A highlights *“more roads, more houses and more hard surfaces”*. These increases can be regarded as ‘urban creep’. Upon reflection interviewee C, simply states *“urban expansion”*. Lastly, socioeconomic issues are highlighted by only two interviewees A and B, who state *“Government and European farming policies impacting vegetation removal upstream”* plus *“planning and development control”*. The response of interviewee A may point to an inherent problem within Government for dealing with flood hazards. Although these two individual socioeconomic issues are not covered in chapter two this emphasizes the need for more probing into the cause and effect such issues. The factors identified include climate change, urbanisation, unsustainable development, and socioeconomic issues.

5.2. ADEQUACY AND INFLUENCES ON BUILT ENVIRONMENT PROTECTIONS PROVIDED

The common consensus across all interviewees was that currently enough is being done when considering all the protection of the built environment although all agreed that more could still be done. This question has supplied an initial closed response, but then also opened discussions probing deeper into the factors that may influence protection. The most mentioned of the three highest factors highlighted was the financial aspect, this theme could again be transferred into sub themes to explore the issue in greater detail but the exploration of this aspect was limited in this study. Interviewees A, B and C all identified financial factors as influencing protection. Interviewees A and B highlighted the financial constraints on Governments *"with the limited resources of governments and organisations"* and *"funding constraints from the Government"*. The opinions of the interviewees are also views shared by Shrubsole (2015) who points out the lack of government budget allowance to combat the issue.

All but one of the interviewees identified future developments as having an impact on the levels of protection across the UK, with interviewees A, D and C all mentioning that the impact of future developments will have on protection, these views can be encapsulated by interviewee A; *"New developments that don't do enough to protect themselves, often ignoring advice from the environment agency or other organisations or other organisations as they still carry on with developments that aren't appropriate for the location"*. The research of Ingirige *et al.* (2008) correlates these views in respect to the future increase of flooding in the UK and how the built environment will play a primary role in flooding protection both now and in the future. Another primary factor identified by interviewees A, C and D was education, this was discussed by A, who a pointed out the lack of education is an attributing factor adversely affecting protection. Whereas, Interviewee C highlights *"researching the extent of current flood protection development"*, this could aid improvement of protection. Finally, interviewee D reflects on the factor by noting an increase in education *"people are more aware of the issue"*. Finally, interviewee A and B mentioned the existing environment and the practicality of protection respectively, although these factors arenot as prominent, the need to provide practical solutions to protecting existing infrastructure is of paramount importance. Thorne *et al*. (2007) agrees with these views as they point out existing hard drainage is not adequate. The factor identified are finance, buildability, education, existing environment, future development.

5.3. HOW THE LEEDS FLOOD ALLEVIATION SCHEME IS FINANCED

From the data supplied by the thematical analysis has provided us with the information required to start the formation of the situational paradigm. From asking this question it opens discussion on the effectiveness of the funding model and provides an insight into the Interviewees knowledge of where the funding comes from. We can see that interviewees A, B and D identified all the contributing parties, this was in stark contrast to interviewee C's response who only identified *"Leeds City Council"* as contributing, because of the responses the three most knowledgeable Interviewees were probed as to their opinions of the effectiveness of the finance model. Interviewee A highlighted that there was a *"number of strands of funding for the scheme that contributes to greater project security"*. From this response, it is clear the interviewee was in favour of the funding model. Upon discussion Interviewee projected the theory that greater involvement from a wide range of stakeholders would ultimately increase both protection and overall benefits for the wider community *"there's a mix of funding that comes forward and this was a pretty good model"*. When questioned upon the funding's effectiveness interviewee D simply put *"yes the model is effective"* the views of these interviewees may point to a future model of urban flood defence funding, Specifically considering the future flooding report (2004) who outline a need to increase in flood spending over the coming years. This question firstly aided progression of the situational paradigm by identifying the specific funding avenues utilised for the LFAS scheme. In addition, the responses highlight the levels of funding received from different public departments. The funding sources identified are Leeds City Council, Environment Agency, Regional funding, Department of Environment, Food and Rural Affairs.

5.4. PERCEIVED ADEQUACY AND ISSUES WITH CURRENT GOVERNMENT SPENDING

Upon responding to the initial question all interviewees responded with a yes to the inadequacy of funding apart from interviewee D who poses the question *"A difficult one, because is spending ever going to be adequate?"* This response outlines the general theme for the preceding discussions; although respondents answered with a *"yes"* they all went on to discuss the varying factors attributing to the adequacy of funding.

Interviewees A, B and C all noted that in some way future developments affect the adequacy of government spend, Interviewee A suggests that *"looking at how future developments are put together, you know, thinking outside the box there as well, there is certainly more that I am sure can be done"*. Interviewee B has a similar outlook on the issue, supporting that greater emphasis is required on planning for flood protection on future developments. These views tie in directly to the responses of interviewees C and D who both reflect on the current approach to flood funding. Interviewee D identifies a *"more reactive than proactive with spending"*. These views are shared by interviewee C who states, *"Unfortunately though funding for these schemes tend to be more of a 'reaction' to seasonal conditions rather than proactively developing high risk areas that are yet to be affected"*. The above issues portray a situation that where funding is used reactively in responding to current issues. Considering the limited budgets of government this leads to an increased need for a pro-active approach to funding, by involving future developments plans in currents funding schemes greater value for money could be attained. The issues of concern identified from the interviews are reactive over proactive approach, availability of budgets, future developments, and effectiveness of spending. Despite the interviewees' concern about the adequacy of spending on defending Leeds from flood, they all agreed that Leeds have been made less vulnerable. Interviewees suggested the use of sustainable urban drainage. Both interviewees B and D identified this method as being key to reducing the risk of urban flooding in the Leeds catchment. Interviewee B proceeds to elaborate on the specific elements that such a system would consist of *"introducing water gardens and you know going down to the level of individual properties where, you know, using water butts as a means of storage"*. The use of such methods was advocated by Thorne *et al*., (2007) who describes the benefits of using sustainable Urban Drainage (SUDS) as *"unequivocal"*. Interviewee has identified the need for *"investment in new infrastructure and new build environment"* to increase flooding protection in the future. This view supports the conclusions of Stern (2007). Finally, interviewee C specifies a method of construction previously unknown to the researcher *"future-proofing"*. This method has not been explored previous to this discussion.

There was a resounding agreement upon responses that the Leeds Flood Alleviation Scheme will be cost effective, with interviewee A replying with a resounding *"absolutely yeah"* that captured the general tone for all interviewees' thoughts. Upon discussion interviewees A and B highlight the process used in the project to ensure the cost benefits for the scheme were achieved with each highlighting a *"business case"* and a *"cost benefit analysis"*. From these responses, extensive research was undertaken through the schemes conception. Interviewee C provided the greatest insight into the cost effectiveness of the scheme by simply comparing the cost of the defences to the potential cost of damages; he concluded that the cost of repairs over a 50-year period *"would be 2.5 times higher than the total cost of the LFAS"*. Interestingly, the interviewees displayed a convincing general knowledge of the construction technology the scheme utilises, with each providing exploration of certain elements.

The most frequently mentioned element was the moveable weirs with interviewee D stating *"This will be the first time this innovative technology has been used in the UK"*. Essentially, this new technology has been a key factor in increasing overall protection. Interviewee A proceeds to briefly explain the technology of the moveable weirs *"So there's two major weirs through the River Aire corridor through Leeds and they're being rebuilt to accommodate essentially an air bag system whereby during periods of high river flow the air bags are deflated, the level of the weir drops and that effectively allows water to pass through the system quicker"*. All respondents highlighted the use of the linear defences as a technology used, although only half of the Interviewees mentioned the removal of the Knostrop cut island. This could in retrospect indicate lack knowledge among the project team. The responses provided an insight into the technologies used, these technologies are possible solutions that could be used in other urban areas across the UK, progressing the creation of the situational paradigm. The technologies identified to have been engaged in Leeds are moveable Weirs, linear defences and Island removal.

Interviewees A and B highlighted other different methods of attenuation systems with A mentioning the use of *"upstream storage"* who then goes on to specify an instance where he had worked on a scheme involving such methods *"I have recently been involved in the construction of a new reservoir in Morpeth"*. This shows that alternative measurers are in use across the UK. The second attenuation method highlighted by Interviewee B consisted of *"surplus water drainage"*. The uptake of innovative flood technologies has been slow in the UK according to Lamond *et al*. (2012). Interviewee proceeded to discuss the possibilities of natural drainage as an alternative method specifically Interviewee A states *"there options are construction of sort of more kind of wetland areas"*. These methods can be utilised as part of future development schemes to offset the risk increase caused from urbanisation, the use of environmentally advantageous methods would be welcomed by organisations such as the Royal Society for the Protection of Birds (RSPB).

The final two alternative methods advocated by Interviewees A and D respectively include hard surface measures particularly the use of *"by-pass channels"* which would be appropriate for use in the urban environment. Lastly Interviewee D mentions the *"wider use of silt control"* which could include dredging; Stuart Agnew MEP is a strong supporter of this method. The other possible methods identified are water storage system, natural drainage system, urban drainage system and river management.

5.5. FURTHER COMMENTS ON THE LFAS

The most common theme arising upon reflection was that the 2015/2016 floods had a negative impact on the LFAS project but upon closer inspection the views of interviewee D provide a more positive outlook *"scheme got off quite lightly"* and proceeding to state that on *"a more oddly positive note I think the floods have actually helped us"*. These views were shared by interviewee A who reiterates that the flooding had *"really focussed the mind to make things happen"*. Reflecting on the positive attitude of interviewees A and D, Interviewee B also noted that the *"scheme held up pretty well"*. Portraying a situation where things could have been a lot worse. It is important to note that although there may have been a silver lining all Interviewees opened by listing the negative impacts of the project. With interviewee C stating that *"Knostrop Weir was severely affected by the winter flooding"*. In addition, the remaining interviewees went on to highlight the time and cost implications of the flooding. Specifically, interviewee C mentioned the commercial impacts and interviewee B the impacts on project programme.

5.6. THE SITUATIONAL PARADIGM

The situational paradigm in the case of Leeds, UK is a model suggesting a solution to intra-urban flooding with a particular focus on structural flood defences. The creation of the model is a result of the triangulation of both the primary and secondary data obtained from this study. The data has been used to identify the key components of the 'Leeds Paradigm'. The key components in the case of LFAS were identified as a situational pattern. The next stage of the process is the creation of the situational paradigm, which will take the knowledge gained from the Leeds model, transposing onto this the patterns and interrelationship of factors of other situations, leading to the generalisation of the 'Leeds Model', thereby creating the 'situational paradigm' for the factors of and solutions to intra urban flooding generally and an outline of the critical success factors of urban flood schemes. This paradigm can then be applied to other major UK urban environments, furthering the appreciation of possible risks and potential solutions. Ultimately, the 'situational paradigm' can be used for the selection and justification of future urban flood defence schemes, in summary; the emerging patterns identified in this research and required for the creation of the paradigm is presented in Figure 1.

Figure 1: The 'Leeds Model'

6. CONCLUSIONS

The discussions presented general themes that are not too dissimilar to the points identified in the literature, with climate change being identified along with increased urbanisation as major attributing factors to the increase of flooding frequency and severity. Following from this there was a common consensus that considering current economic climate and the varying constraints upon government that currently enough was being done to adequately protect the built environment. Through the various discussions surrounding the situation in Leeds it was apparent that the current scheme was considered cost effective, offering an adequate level of protection while being funded effectively by an innovative method of public funding, involving various key stakeholders; thus, justifying the schemes outlay. The latter discussions of the interviews were centred on the construction technologies involved with flood defences and the current knowledge among construction professionals. Through exploration, many alternative methods of flood defence were identified, with relative gaps in interviewees' knowledge occasionally. Towards the creation of a situational paradigm, additional case studies are necessary to achieve a wider sample of results, thus, improving correlation and reducing the risk of biased results by increasing the variable saturation. This will be considered in further works.

7. REFERENCES

ABI, 2007. *Adapting to our changing climate: a manifesto for business, government and the public* [online]. Available from:http://static1.1.sqspcdn.com/static/f/270724/1875476/1220367254470/climate_change_final.pdf?token=3393C2G8amE7WS6uDMNDVLfB75c%3D [Accessed 24 Mar. 2016].

Blackmore, R. 2015. *The Economic Impact of the NRFA Peak Flow Database. Research Impact Consulting*.[online]. Available from: https://www.ceh.ac.uk/sites/default/files/The%20Economic%20Impact%20of%20the% 20NERC%20 Peak%20Flows%20Database_0.pdf [Accessed 24 Mar. 2016].

Bosher, L.S., 2007. *Social and Institutional Elements of Disaster Vulnerability: The case of south India*. Bethesda: Academia Press.

Bosher, L.S., 2008. *Hazards and the built environment: attaining built-in resilience*. New York: Taylor and Francis.

Corbin, J., and Strauss, A., 2008. *Basics of qualitative research: Techniques and procedures for developing grounded theory*. London: Sage.

Foresight Report, 2003. *Foresight Future Flooding.* [online]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/300332/04-947-flooding-summary.pdf [Accessed 24 Mar. 2016].

Global Humanitarian Forum. 200. *The Anatomy of a silent crisis Global Humanitarian Forum*. [online] Available from: http://www.ghf-ge.org/human-impact-report.pdf [Accessed 24 Mar. 2016].

Harper, M. and Bowern, M. 2016. *RSPB position on dredging in the Somerset Levels and Moors - Martin Harper's blog - Our work - The RSPB Community* [online]. Available from: http://www.rspb.org.uk/community/ourwork/b/martinharper/archive/2014/02/01/rspb-position-on-dredging-in-the-somerset-levels-and-moors.aspx [Accessed 24 Mar. 2016].

IME, 2013. *Natural disasters saving lives today, building resilience for tomorrow* [online]. Available from: http://www.indiaenvironmentportal.org.in/files/file/natural-disasters-saving-lives-today-building-resilience-for-tomorrow.pdf [Accessed 10 Mar. 2016].

Ingirige, M. J. B., Haigh, R., Malalgoda, C. I., and Palliyaguru, R. S., 2008. Exploring good practice knowledge transfer related to post tsunami housing re-construction in Sri Lanka. *Journal of Construction in Developing Countries*, 13(2), 21-42.

Lamond, J., Booth, C., Hammond, F., and Proverbs, D., 2011. *Flood hazards: Impacts and responses for the built environment*. CRC Press: Florida.

Leinster, P. 2009. *Flooding in England: a national assessment of flood risk*. Almondsbury: Environment Agency.

Malalgoda, C. I., Amaratunga, R. D. G., and Pathirage, C. P., 2010. Exploring disaster risk reduction in the built environment. In: Barret, P., Amaratunga, D., Haigh, R., Keraminiyage, K., Pathirage, C., ed. *CIB 2010 World Congress*, Salford 10 – 13 May 2010. Salford: University of Salford.

McGlade J., 2002. Thames navigation and its role in the development of London. In: *2002 London's Environment and Future (LEAF) Conference*, 9-11 September, University College London, United Kingdom.

Munich, R., 2003. *Press Dossiers: Climate Summit in Cancún Munich Re* [online]. Available from: https://www.munichre.com/en/media-relations/publications/press-dossiers/cancun-2010/index.html?QUERYSTRING=global climate change [Accessed 24 Mar. 2016].

Neumayer, E., and Barthel, F., 2011. Normalizing economic loss from natural disasters: A global analysis. *Global Environmental Change*, 21(1), 13-24.

Ofori, G., 2002. Construction industry development for disaster prevention and response. In: *i-Rec International Conference on Post-Disaster reconstruction: Planning for reconstruction*, 23-25 May, Université de Montreal, Canada.

Pielke, R., Gratz, J., Landsea, C., Collins, D., Saunders, M., and Musulin, R., 2008. Normalized Hurricane Damage in the United States: 19000-2005. *Natural Hazards Review*, 9 (1), 29-42.

RICS, 2015. *Flooding: issues of concern to RICS surveyors and valuers (Residential property)*. London: RICS.

Shrubsole, G., 2016. *Flood risk and climate change – protecting our homes communities and livelihoods* [online] Friends of the earth. Available from: https://www.foe.co.uk/sites/default/files/downloads/flood-briefing-september-2014-47494.pdf [Accessed 24 Mar. 2016].

Soetanto, R., Proverbs, D., Lamond, J. and Samwinga, V. 2008) Residential properties in England and Wales: an evaluation of repair strategies towards attaining flood resilience. In: Hazards and the built environment: attaining built-in resilience. London: Taylor and Francis, pp. 124-149.

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., and Miller, H. L. ed., 2007. Climate change 2007-the physical science basis [online]. Available from: http://www.irpi.to.cnr.it/documenti/IPCC_2007/AR4WG1_FrontMatter-v2.pdf [Accessed 24 March 2016].

Stern, N., H., 2007. *The economics of climate change: The Stern review*. Cambridge: Cambridge University Press.

Thorne, R. C., Edward, P. E., and Penning-Roswell, E. C., 2007. *Future flooding and coastal erosion risks*. London: Thomas Telford.

Wheater, H., and Evans, E., 2009. Land use, water management and future flood risk. *Land Use Policy*, 26, S251-S264.

Wuthisuthimethawee, P., 2016. Disaster and Climate Change. In: *Ciottone's Disaster Medicine*. Ciottone, G.R., Biddinger, P.D., Darling, R.G., Fares, S., Keim, M.E., Molloy, M. S. and Suner, S. (eds), 2nd edn, Philadelphia: Elsevier, pp. 47-52.

A STUDY ON THE APPLICATION OF ECONOMIES OF SCALE IN THE CONSTRUCTION INDUSTRY: THE SRI LANKAN PERSPECTIVE

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ABSTRACT

The application of economic concepts acts as a catalyst to enhance the productivity and quality in the industries such as automotive, transportation and tourism. Economies of Scale (EOS) is such a concept, which could be applied to address the above concern. This research therefore explored the application of EOS to the construction industry. The study adopted a qualitative approach by conducting structured interviews among 14 participants representing consultants and contractors in the construction industry. Subsequently, a content analysis was performed to analyse the data collected, with the aid of NVivo 11. Considering the views of experts, the application of EOS concept is limited to pre-cast elements in both building and civil engineering projects in the construction industry. Majority of the experts opined that application of EOS concept is limited in the construction industry mainly due to unawareness on applicability of EOS (71%) and unique nature of the construction industry (43%). Further, it was identified that uncertainties in the construction industry act as the major barrier to the application of EOS. Confirmation of drawings at the initial stage, conducting training sessions and researches are strategies to promote the use of EOS in the construction industry, which in turn would enable direct economic growth via price efficiencies.

Keywords: *Construction Industry; Economies of Scale; Pre-cast Elements; Sri Lanka.*

1. INTRODUCTION

Needs are based on physiological, personal, or socio-economic requirements necessary for functioning of human life. On the other hand, wants are a means to fulfilling those needs. Usage of limited resources, which have unlimited commitments is a significant concern to individuals and societies. The term 'Economics' is, therefore defined as the studies carried out to explore the methods of how societies use limited resources to fulfil unlimited human wants (Samuelson and Nordhaus, 2005). It would no longer exist, if resources are adequate to fulfil all human wants (Manser, 2005).

Construction is an industry where several resources are being manipulated. Nagaraju *et al*. (2012) opined that money, men, material, machinery and other resources are manipulated within construction projects. Enhanced productivity, quality, efficiency and high-class workmanship are required for the success of construction projects (i.e. completed within cost and time stipulated). Waris *et al.* (2014) are of the view that economic concepts enable a careful management of resources to avoid unnecessary resource consumption or wastage. Thus, the application of economic concepts could act as a catalyst to speed up the construction projects without compromising the quality (Waris *et al.,* 2014). With that note, it is important to identify the applicability of economic concepts to construction projects.

Anecdotal evidences suggest that the micro economic concepts of EOS can be applied in the construction industry. The EOS could be used as a tool, for winning construction projects as it provides competitive advantages for the industry. However, far too little attention has been paid to apply EOS concept to the construction industry. This research therefore explores the application of EOS to the construction industry in Sri Lanka.

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2. LITERATURE SYNTHESIS

The concept of EOS originates from macroeconomics (Finkel, 1997). The term EOS is referring to the increase in productivity or decreases in average costs of production that arise from increasing all the factors of production in the same proportion (Samuelson and Nordhaus, 2005). Similarly, Sloman (2007) defines EOS as the concept where lower cost per unit output achieved through increasing the scale of production.

Literature revealed set of contributory factors as they are the tools of understanding EOS concept as listed below. The fundamental focus of contributory factor is clarity.

- Specialization and division of labour

Anecdotal evidences proved that large firms use division of labour to enhance their productivity (Sloman, 2007). As a result, those become specialized in their particular tasks. Higher performance could be achieved since the tasks are handled by the expertise (Husan, 1997). For example, in construction sites bar bending and bar cutting is done by special skilled labours and sophisticated equipment are operated by specialized operators.

- Container principle

This is linked to the cubic law, where doubling the height and width of a building leads to a more than proportionate increase in cubic capacity. To increase the capacity by eight-fold, the surface area needs to be increased by only four-fold (Sloman, 2007). Similarly, Husan (1997) mentioned that economies of increased dimension occur where cost increment is less rapid than capacity. Further, costs increase with surface area, while output increases with volume (or capacity) of additional units of plant and equipment.

- By-products

Sometimes by-products are generated in larger firms (Sloman, 2007). They can be sold or converted into another usable product.

- Multi stage production

Several economies can be attained through merging the activities when the production is carried out in different stages (Sloman, 2007). EOS occurs due to the higher levels of production yield proportional savings in stocks (Husan, 1997).

- Learning by doing (experience curve theory)

Unit costs decrease with increasing experience as they cut waste and find the most productive means of producing output (Chiang *et al*., 2008). The idealized pattern describing this kind of technological progress in a regular fashion is referred to as a learning curve, progress curve, experience curve, or learning by doing (Chiang *et al*., 2008).

Literature further elaborates the application of EOS in tourism, transportation and manufacturing industries. For example, Shi and Smyth (2012) analysed the change of long-run cost with output by estimating EOS at the industry level in transport, retail trade and accommodation recreational services, which closely aligned to tourism and proved that returns of the tourism industry can be maximized through specialization and EOS. Similarly, Sheu and Chen (2014) explained that when quantity becomes large, EOS usually facilitates the significant reduction of cost in transportation networks. Further, Worthington and Higgs (2014) highlighted that efficient production would be attained by adjusting the scale of production to most appropriate size for outputs produced in Australian urban water utilities. Moreover, Husan (1997) examined the importance of EOS in the automotive industry. By assessing the components which influence the cost of a communal rainwater harvesting system, Gurung and Sharma (2014) suggested that cost of communal rainwater harvesting system varies with the number of households.

In terms of EOS application in the construction industry, Ahadzie *et al.* (2008) found that Mass House Building Projects (MHBP) have applied EOS significantly and it became one of the critical success criteria for winning a competitive tendering. Parker (1997) indicated that large building units consist of greater EOS, while the small and medium sized units are more likely to reveal decreasing returns to scale. A common expectation is that EOS in road construction could lower the unit cost of constructing along with the length of the road (Atsushi, 2007). Road construction must exhibit EOS, meaning that the average construction cost decreases with the length of road contracted due to flexible allocation of labour and equipment and necessary overhead costs (Atsushi, 2007). Manser (2005) emphasized that, when cost and time become crucial, construction moves from off-site to use of prefabrication techniques, where the space for technical EOS is much greater. In a similar way, Chiang *et al*. (2008) enlightened that prefabrication was adopted not because of client requirement, but as it enabled EOS, enhanced productivity and managerial efficiency. On other hand, some of the researchers are of the view that application of EOS in the construction industry is at a minimal level due to several reasons. For example, Sobol (2007) and Dunning (2014) indicated that less adoptability to new technology and lack of willingness to change limit the application of EOS. Meduri and Annamalai (2013) explained that financial difficulties faced by small contractors in handling several projects simultaneously are another barrier for the use of EOS in construction projects.

3. RESEARCH METHODOLOGY

As per the nature of the subject area, in construction industry, the application of EOS concept is very limited. It was very rare to find a case, which applies EOS within the construction industry; therefore, this study employed a qualitative approach conducting structured interviews to investigate the applicability of EOS within the construction industry in Sri Lanka. The unit of analysis for this research was the experts who have knowledge on application of economic concepts in the industry. Experts interviewed were selected with due considerations to their backgrounds, field of involvement and exposure to subject matter of the current research. Accordingly, altogether, fourteen (14) participants representing consultants and contractors were interviewed until the data get saturated. Here, the sample was selected using the convenient sampling method, which can be used when focusing on a limited number of informants where the in-depth information provides optimal insight on issue which is little known. Most of the interviewees occupied managerial positions and involved in project management, cost management and cost control activities. A summary profile of participants is presented in Table 1.

Table 1: Profile of the Participants

Representative Sector	**Number of Participants**		**Work Experience**	**Number of Participants**	
	No.	Percentage		No.	Percentage
Contractor	09	64%	Less than 10 years	03	22%
Consultant	05	36%	10-20 years	09	64%
			Above 20 years	02	14%
Total	14	100%	Total	14	100%

As observed from Table 1, majority of the experts (64%) belonging to the contractor organisations whose designations are: Quantity Surveyors, Managing Directors, Project Managers, Structural Engineers, General Manager Estimation and Contracts, and Contracts Manager. Rest of the experts belong to the consultancy organisations and include Directors, Quantity Surveyors and Architects. Almost all the interviewees are in the category of more than 5 years of experience in their field of work in the construction industry. Further, 78% of the experts have more than 10 years of experience while 14% of the experts have more than 20 years of experience. Accordingly, experts' views are collected to explore the current status of application of EOS concept, to identify the reasons and barriers for limited applicability of EOS, and proposed strategies to overcome those barriers. Subsequently, a content analysis was carried out to analyse the collected data with the aid of NVivo 11.

4. DATA ANALYSIS AND FINDINGS

Since literature is not evident on proper investigations carried out on application of EOS in Sri Lankan construction industry, this study explores the current status of application of EOS concept, reasons and barriers for limited applicability of EOS and suggest strategies to overcome those barriers. Accordingly, structured interviews were conducted with the intention of collecting experts’ views on aforementioned aspects. Later, opinions of interviewees were analysed using NVivo 11 and the results of the analysis are presented in subsequent sections.

4.1. *MOSTLY APPLICABLE AREA OF ECONOMIES OF SCALE WITHIN THE CONSTRUCTION INDUSTRY*

This section summarizes the views of the experts regarding the application of EOS concept in construction projects. Initially, participants were questioned on their experience on application of EOS under the major types of construction projects and sub projects which comes under each type of construction. Results are presented in Table 2.

Table 2: Application of EOS within Building Construction and Civil Engineering Construction

	No. of Responses	Percentage	Type of Project	No. of Responses	Percentage
Building	03	22%	Apartment complexes	03	21%
			Hotel buildings	02	14%
Civil Engineering	03	22%	Highway construction projects	02	14%
			Road construction projects	01	7%
Building and Civil Engineering	08	56%	Road, bridge, culvert construction and dam construction	06	43%
			Apartments complexes	05	36%
			Other residential building construction projects	02	14%
			Hotel projects	02	14%
			Highway construction projects	01	07%
			Hydro power and power plants	01	07%
			Water supply projects	01	07%
			Ports	01	07%
Total	14	100%			

Amongst all interviewees, 56% of the experts have applied the EOS concept in both building and civil engineering construction projects. Under building construction projects, majority (21%) of the experts have practiced it for apartment complexes while 14% in hotel construction projects. Besides, 14% of the experts have applied EOS in highway construction projects under civil engineering construction. Relating to building and civil engineering, majority of the experts (43%) have applied EOS in road, bridge, culvert, and dam construction projects. Further, EOS concept is applied by 36% experts under apartment projects while only 14% experts have applied it on other residential building construction projects and hotel projects. Overall, in Sri Lanka, the EOS concept has significantly applied in building construction projects, especially in apartment complexes, hotel projects, road and highway construction projects.

Subsequently, experts were asked to comment on key areas, where EOS is applied within identified types. As per the data collected through interviews, four areas were identified where EOS concept is applied under the construction projects, whereas three areas under the civil engineering projects. Table 3 presents the results derived from the analysis.

As per Table 3, majority (91%) of the interviewees who applied EOS concept in civil engineering projects, stressed that it is mostly applied in pre-cast concrete elements. Contraly, 64% of the experts who applied EOS concept in building construction projects, emphasized that it is mostly applied in both pre-cast and pre-fab elements. Further, 46% among the interviewees who applied EOS concept in building construction projects, mentioned that this concept can be applied in formwork systems. One of the contract administration experts has specified the nature of formwork as steel, where this can be highly applied more efficiently. However, 36% indicated the possibility of applying the concept for aluminum components. In addition, 27% of the experts mentioned the applicability of EOS concept within laying asphalt and 18% of the experts agreed to the use of the concept in laying Aggregate Base Course (ABC), since significant quantities are available in those items in road and highway construction projects. Considering the views of the experts it was identified that EOS concept is highly applied in pre-cast elements both in building construction and civil engineering construction projects, even though there is a possibility of applying the EOS concept for steel pre-fab elements under building construction rather than pre-cast concrete elements.

Table 3: Mostly Applicable Areas of EOS within the Construction Industry

Applicable areas	Sources	References	Percentage
Mostly applicable area of EOS within the construction industry	14	32	
Under building construction projects	11	17	
Pre-cast concrete and pre-fabricated steel elements	07	07	64%
Formwork	05	05	46%
Aluminum components	04	04	36%
Concrete	01	01	09%
Under civil engineering projects	11	15	
Pre-cast concrete elements	10	10	91%
Laying Asphalt	03	03	27%
Laying ABC	02	02	18%

In another point of view, one of the large building design experts pointed out that EOS can be mostly applied within the design. He was of the opinion that EOS concept must be effectively applied in designing where it helps to economize the design. One of the budget estimating experts stated that EOS concept can be applied at the material procurement stage.

Majority of the experts were of the opinion that EOS concept can be applied even up to purchasing new plant and equipment as well. It is safe to say that EOS can be applied within various stages of a construction project such as design, procurement and construction by considering the opinions. At the construction stage, EOS can be applied even up to the installation of new plant and machinery.

4.2. CONTRIBUTORY FACTORS FOR ECONOMIES OF SCALE

The study identified contributory factors of EOS concept, which accelerate the cause of EOS within the construction industry. Results derived from the analysis of experts' opinions are shown in Table 4.

Table 4: Contributory Factors for EOS

Factors	Sources	References	Percentage
Contributory factors for EOS	14	30	
Division of labour	13	13	93%
Specialisation of labour	09	09	64%
Gained discount rates due to bulk purchasing	08	08	57%
Application of new technology or changes in methodology	05	05	36%
Shared fixed costs	04	04	29%
Operational efficiencies in machineries	04	04	29%
Learning by doing (experience curve theory)	04	04	29%
Generation of by-products	01	01	07%

According to Table 4, majority of the experts (93%) specified enhanced labour productivity due to the divisions of labour as a key contributor of EOS. Further, 64% of the experts were of the opinion of that specialization of labour accelerates the EOS. Additionally, 57% of the experts were of the opinion that discount rates obtained due to the bulk purchasing causes EOS. Moreover, application of new technology or changes in methodology is considered as a contributory factor by 36% of the experts. In addition, 29% of the experts were with the view of that shared fixed costs, operational efficiencies in machineries, and learning by doing (experience curve theory) cause EOS. According to one of the budget estimation experts, generation of by-products also can be a contributory factor of EOS.

4.3. REASONS AND BARRIERS FOR LIMITED APPLICATION OF EOS WITHIN THE CONSTRUCTION INDUSTRY

The review of literature survey identified that application of EOS concept is limited in the construction industry compared to other industries. Agreeing to that, 86% of the experts emphasized that other industries apply these concepts much more effectively when compared with the construction industry. According to the experts, this concept is mostly applied within manufacturing or production industries. One of the cost controlling experts explained the reason for the high applicability of the concept in aforementioned areas as follows: "*Most of the time manufacturing firms decide their cost at the end of the product. When it comes to the construction industry, cost is concerned at the beginning of the project at the tendering stage. The cost is estimated at the beginning even without knowing the product. In such situations, we just try to bid for the project and win it, we are not going to apply these concepts and reduce the cost*". Further, majority of the experts were of the opinion that repetitive nature of products in manufacturing industry requires the EOS concept as it can be easily practiced there. Overall, 93% of the experts were not satisfied with the current application of EOS within construction industry.

Therefore, this study identified the reasons for limited applicability of EOS concept within the construction industry in Sri Lanka and findings of the analysis are presents in Table 5.

Table 5: Reasons for Limited Applicability of EOS

Reasons	Number of Experts	Percentage
Designers' unawareness on applicability of EOS concept	10	71%
Unique nature of the construction industry	06	43%
Changes in initial design	03	21%
Limited number of repetitive features within the designs	03	21%
High risks and uncertainties involved within the construction industry	03	21%
Lack of willingness to change	02	14%
New technology is not that much adopted	02	14%
Barriers in procuring raw material with discounts	02	14%
Lack of time between awarding and the commencement	02	14%
Difficulty in handling projects simultaneously	01	07%
Deficiency of analysed databases between per unit cost and number of items produce	01	07%
Price is determined before the production process begins	01	07%
Limited number of researches were conducted on these area	01	07%

As Table 5 presents, majority of the experts (71%) identified the reason for lower applicability as the designers' unawareness on applicability of EOS concept in the construction industry. Unique output has been identified as the second reason to limited applicability of EOS. One of the contract administration expert stated that "*construction is always associated with risk. Always the conditions are changing in the industry unlike in the manufacturing industry. It has repetitive elements, large quantities, high value items, low value items, public areas, accommodation and so many other things. It is an industry which is associated with lot of sub sections. Therefore, one construction product may not be similar to another*". On the other hand, uniqueness makes less number of repetitive elements.

Subsequently, experts were questioned on existing barriers for application of EOS within Sri Lankan construction industry, which are caused as results of over identified reasons. Identified barriers in applying EOS are presented in Table 6.

Table 6: Barriers in Applying EOS

Barriers	Sources	References	Percentage
Barriers in applying EOS within the identified areas	11	15	
Uncertainties in construction industry	05	05	36%
Lack of knowledge in economic concepts	04	04	29%
Occurrence of variations	02	02	14%
Limited storage facilities	02	02	14%
Improper distribution of tasks	01	01	7%

As per Table 6, 36% of the experts stated that uncertainties in construction industry act as a barrier when applying this concept within those particular areas. Adverse climatic or environmental conditions can be the reason for uncertainty. The experienced civil engineering expert was also of the same view that applicability of EOS is less in civil engineering projects due to the unforeseeable physical conditions encountered. Besides, lack of knowledge in economic concepts has been commented as a barrier to apply EOS by 29% of the experts. In addition to that, 14% of the experts mentioned occurrence of variations and limited storage facilitiesas barriers. One of the project control experts said that *"if there is a possibility of occurring variations, contractors are reluctant to purchase materials at once and they will not obtain the discount advantages"*. At last, improper distribution of tasks is opined by only one expert.

4.4. PROPOSED STRATEGIES TO OVERCOME THE BARRIERS

At the end of interviews, experts were asked to comment on the strategies in overcoming aforementioned barriers. Considering the experts' views, strategies shown in Table 7 were identified to overcome limited applicability of EOS in the construction industry.

Table 7: Proposed Strategies to Overcome the Barriers

Strategies	Sources	References	Percentage
Strategies to overcome barriers	09	09	
Confirmation of drawings at the initial stage	05	05	36%
Conducting training sessions	02	02	14%
Conducting researches	02	02	14%

Accordingly, 36% of the experts were of the opinion that the best way to overcome the aforementioned barriers is to confirm drawings and obtain detail drawings as early as possible. In addition, 14% of the experts were of the opinion that management of the organizations should conduct some training sessions in order to provide a good knowledge on applying economic concepts in construction projects. Another 14% of the experts stated that the best way to overcome barriers is conducting some researches on these economic concepts and providing the knowledge to the industry.

5. DISCUSSION AND CONCLUSIONS

Application of EOS is limited to certain areas such as mass house building projects, road projects and highways in construction industry compared to manufacturing, automobile and apparel industries. Although its application is limited, it is a known concept within the Sri Lankan construction industry and found mostly applied in pre-cast concrete element under the civil engineering projects while applying in both pre-cast concrete and pre-fabricated steel elements of building construction projects. This has been the situation in the international context (Manser, 2005 and Chiang *et al*. 2008). Further, it was identified that production of pre-cast / pre-fabricated elements has more opportunity to adhere with EOS as they cast within a factory under the controlled conditions of temperature. Further, formwork, aluminium components and concrete under building construction projects and laying asphalt and laying ABC under the civil engineering projects, were identified as the most applicable areas of EOS within the construction industry. Moreover, it can be applied within design stage, procurement stage, project execution stage and within the execution stage even up to purchasing of new plant and equipment.

In terms of contributory factors of EOS, unlike previous studies, this study has revealed extensive set of factors including division of labour, specialisation of labour, gained discount rates due to bulk purchasing, application of new technology or changes in methodology, shared fixed costs, operational efficiencies in machineries, learning by doing, and generation by-products. This study confirms that application of EOS concept is limited in the local context for the similar reasons stated in the literature. However, this study further revealed eight reasons which reduce the application of EOS within the construction industry in Sri Lanka. They are: unique nature of the construction industry, initial design changes, limited number of repetitive features within the design, high risks and uncertainties involved, lack of time between awarding and the commencement, deficiency of analysed databases between per unit cost and number of items produce, pre-determined prices, and limited research and development. Consequently, uncertainties exist within the construction industry has been identified as the main barrier to the application of EOS in Sri Lankan construction industry as construction is always cope with the uncertainties since construction products expose to the external factors. Accordingly, it is recommended to confirm the detail drawings at the initial stage of constructions and to conduct regular training sessions and increase the number of researches carried out focusing the construction industry, in order to overcome existing barriers.

According to the finding of the study, there is a high possibility to apply EOS within apartment complex projects or road construction projects, which consist of more repetitive elements. If a firm runs at EOS, that firm has the opportunity to enhance the profit figures. In future, there would be more applications of EOS within the areas such as external cladding, curtain walls, electrical cables and layering PVC pipes. Finally, it is recommended for a construction firm to apply the EOS concept for their products and obtain price efficiencies and not to increase the quantity to a level at while where diseconomies of scale are applied and generate price deficiencies.

6. REFERENCES

Ahadzie, D., Proverbs, D. and Olomolaiye, P., 2008. Critical success criteria for mass house building projects in developing countries. *International Journal of Project Management*, 26(6), 675-687.

Atsushi, L., 2007. Aid and competition in procurement auctions: A case of highway projects. *Journal of International Development*, 19(7), 997-1015.

Chiang, Y., Tang, B. and Wong, F., 2008. Volume building as competitive strategy. *Construction Management and Economics*, 26(2), 161-176.

Dunning, J., 2014. *Economic analysis and multinational enterprise.* 3rd ed. Oxon: Routledge.

Finkel, G., 1997. *The economics of the construction industry*. Armonk, New York: M.E. Sharpe.

Gurung, T. and Sharma, A., 2014. Communal rainwater tank systems design and economies of scale. *Journal of Cleaner Production,* 67(1), 26-36.

Husan, R., 1997. The continuing importance of economies of scale in the automotive industry. *European Business Review*, 97(1), 38-42.

Manser, J., 2005. *Economics: A foundation course for built environment.* New York: Taylor & Francis.

Meduri, S. and Annamalai, T., 2013. Unit costs of public and PPP road projects: Evidence from India. *Journal of Construction Engineering and Management*, 139(1), 35-43.

Nagaraju, S., Reddy, B. and Chaudhuri, A., 2012. Resource management in construction projects. *Engineering Science and Technology*, 2(4), 660-665.

Parker, E., 1997. The effect of scale on the response to reform by Chinese state-owned construction units. *Journal of Development Economics,* 52(2), 331-353.

Ruddock, L., 2009. *Economics for the modern built environment.* 2nd ed. New York: Taylor & Francis.

Sabol, L., 2007. Technology, change, and the building industry. *Real Estate Review*, 36(3), 1-12.

Samuelson, P. and Nordhaus, W., 2005. *Economics.* 18th ed. New Delhi: Tata McGraw-Hill Edition.

Sheu, J. and Chen, Y., 2014. Transportation and economies of scale in recycling low-value materials. *Transportation Research Part B: Methodological,* 65, 65-76.

Shi, H. and Smyth, R., 2012. Economies of scale in the Australian tourism industry. *Applied Economics*, 44(33), 4355-4367.

Sloman, J., 2007. Essentials of economics. 4th ed. England: Prentice Hall.

Waris, M., Liew, M., Khamidi, M., and Idrus, A., 2014. Investigating the awareness of onsite mechanization in Malaysian construction industry. *Procedia Engineering*, 77, 205-212.

Worthington, A. and Higgs, H., 2014. Economies of scale and scope in Australian urban water utilities. *Utilities Policy*, 31(1), 52-62.

ADAPTABILITY OF GREEN BIM TECHNOLOGY FOR THE GREEN BUILDINGS IN SRI LANKA

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ABSTRACT

To raise awareness of green building constructions, Building Information Modelling (BIM) has been incorporated with unique sustainable strategies. Green BIM technology is a significant innovation of BIM, emerged through the integration of BIM with sustainable strategies, which enhance the sustainable growth of buildings while making better opportunities to improve the performance of green buildings. However, the utilisation of Green BIM technology for existing buildings is less amongst green building practitioners though Green BIM is widely used for design and construction phases of buildings. In the Sri Lankan context, since BIM is not implemented yet in building construction, operation and maintenance, the inherent capabilities of Green BIM technology are hidden and invisible. Thus, an effort is needed to convince and prove the importance of Green BIM technology for green building practitioners. Towards this effort, the research is aimed at identifying the potential of implementing Green BIM technology for the existing green buildings in Sri Lanka where BIM is not applied. Accordingly, a mixed research approach was followed to accomplish the research aim. Literature review revealed that, the data availability required for Green BIM techniques and tools is the critical requirement to implement the Green BIM technology for the established buildings. A desk study was conducted to determine the required data and availability of the data was analysed through a questionnaire survey and a case study. The findings of questionnaire survey demonstrated that, there is an acceptable level of data within the current established green buildings. The results of the case study highlighted the potential of Green BIM implementation for the existing green buildings. Thus, the study concluded by identifying the ability of incorporating Green BIM technology for the existing green buildings considering the real-life context which ensure the Green BIM implementation for the green building sector in Sri Lanka.

Keywords: *Building Information Modelling (BIM); Building Performance; Green BIM; Green Building; Sri Lanka.*

1. INTRODUCTION

In this rapidly rising world population, with the increased demand for scarce resources, and continued pollution to the environment, sustainability has been receiving a major attention in this era (Ghosh, Chasey, and Cribbs, 2015). Consequently, "Green Building" movement has emerged, which later gained an impetus under the concept of sustainability (Krygiel and Nies, 2008; Waidyasekara and Fernanado, 2013). However, though it is proved that green buildings provide numerous benefits for building owners and consumers, according to Richardson and Lynes (2007), there are more deficiencies in green buildings rather than in conventional buildings. Thus, an increasing awareness has been developed in recent years for the use of information technology, to improve green building performance in relation to design, construction, and operation (Solla, Ismail, Elbeltagy and Yunus, 2016).

Since BIM is significantly appreciated in the world as an innovative technology derived from information technology development, building owners have focused to integrate BIM with sustainable design strategies (Wong and Fan, 2013). Moreover, Motawa and Carter (2013) have mentioned that BIM can play a vital role to improve green building performance. Thus, 'Green BIM' has become an enormously popular concept in today construction industry (Sollar *et al.*, 2016). Green BIM is considered as the use of BIM tools, to enhance the building performance and to achieve the sustainability objectives of a building (Krygiel and Nies, 2008).

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However, Wong and Zhou (2015) have mentioned that, the adoption rate of BIM for green building projects is still very less and hence its full potential needs to be explored. Further, Wong and Zhou (2015) have revealed that, the limited knowledge of building owners and practitioners towards Green BIM technology is the main reason for such lower adaptability. Moreover, as mentioned by Barbosa, Pauwels, Ferreira and Mateus (2016), there is a lack of awareness to model the existing buildings in BIM software environment though BIM has widely been used in design and construction phases of buildings. According to Wong and Fan (2013), a systematic review has not yet been carried out, identifying the ways of integrating Green BIM to the existing green buildings.

Hence, based on the aforementioned studies, the research was mainly focused to identify the potential of Green BIM implementation for the existing green buildings. Within the Sri Lankan context, though BIM is still not been implemented, with the growing concern for green building development, Green BIM technology could potentially be incorporated to the existing green buildings. To achieve the research aim, a comprehensive literature review was conducted in order to identify the Green BIM tools and inherent techniques of BIM tools. The input data required for Green BIM tools and techniques were further determined and the availability of identified data were analysed through the data collection and analysis. Finally a case study was conducted as a practical experiment of applying the Green BIM technology, to comprehend the actual capability of Green BIM implementation for existing green buildings. The scope of the research was limited to the population of LEED certified green buildings.

2. LITERATURE REVIEW

2.1. BIM APPLICATIONS IN GREEN TECHNOLOGY

Three main areas of sustainable design, which have a direct relationship with BIM are indicated as material selection and use, site selection and management and system analysis (Shoubi, Shoubi, Bagchi and Barough, 2015). According to, Zanni, Soetanto and Ruikar (2014), BIM contribution to sustainable building design has undergone two perspectives as integrated project delivery and design optimization.

- **Integrated Project Delivery**

It has identified that, there would be numerous problems when handling a green building project, from its inception to completion due to the involvement of various stakeholders within the project. Every project stakeholder including green building consultant takes a part for the project and with clashing opinions and miscommunications of information, many of redundancies could be occurred throughout the project. As in the traditional practice, when resolving all these redundancies through documentation process, the frequency of cycling documents among the stakeholders would be high due to many of refinements, resulting in high costs, mistakes, delays and inefficiencies. As BIM allows an integrated approach for the green building project team, many of redundancies could be eliminated through the improved communication (Park, Park, Kim, and Kim, 2012).

- **Design Optimization**

Design optimization is identified through two steps as creating the basic models using appropriate BIM software (eg: Autodesk Revit) and exporting models to BIM based analysis tools (eg: EcoTest) for the various sustainability analyses / building simulations (Jalaei and Jrade, 2015). There are interoperability standards which functions as data modelling formats, between BIM softwares and analysis tools to ensure the proper data transferring. As examples, Industry Foundation Classes (IFC), IFCXML, COBie, gbXML and ecoXML could be recognized (Redmond, Hore, Alshawi and West, 2012). The building system analyses are incorporated with various functional aspects of a building including structural integrity, temperature control, lighting, ventilation, circulation, energy distribution and consumption (Moakher and Pimplikar, 2012). Hence, there is an ideal opportunity for the sustainability measures and performance analysis of buildings within the usage of Green BIM (Tae, 2012).

2.2. GREEN BIM TOOLS

It is important to identify the Green BIM tools/softwares to carry out various sustainability analyses. Green BIM tools can improve analysis and eliminate the errors of data handling, since it allows analysing the multi-disciplinary information in a single model (Azhar, Carlton, Olsen and Ahmad, 2011). The most commonly used Green BIM tools have been identified as Autodesk ECOTECT, Autodesk Green Building Studio (GBS), Integrated Environmental Solutions (IES) Virtual Environment (VE), Energy Plus and DeST (Wong and Fan, 2013). Graphisoft Eco Designer STAR, Riuska, ArchiVIP and Design Performance Viewer have also been identified as popular BIM based analyses tools (Cemesoya, Hopfe and Rezgui, 2013).

- **Ecotect**

Ecotect owned by Autodesk, is an energy simulation tool which is compatible with BIM softwares (eg: Autodesk Revit Architecture) and used to perform comprehensive building energy performance analysis. Ecotect comprises thermal, lighting and acoustic analyses, including natural and artificial lighting levels, hourly thermal comfort, monthly space loads, project costs, acoustic reflections, reverberation time and environmental impact (Azhar, Brown and Farooqui, 2009).

- **Green Building Studio (GBS)**

Green Building Studio, also owned by Autodesk has been identified as an energy analysis tool to evaluate the environmental impact of individual building components, in the life cycle process of buildings. The lighting and shading analyses are used to assess day lighting and include the LEED Daylight Credit 8.1 feature. The value and cost functions include the lifecycle assessments and lifecycle costs. Green Building Studio is often used to assess multiple design alternatives while ECOTECT is more appropriate for a detailed design visualization and simulation over the performance of a specific sustainable design (Azhar *et al*., 2011)

- **Integrated Environmental Solutions' Virtual Environment (IES'VE)**

Integrated Environmental Solutions' Virtual Environment software is identified as an integrated building performance analysis tool. Analyses are addressed the issues of solar, lighting, energy, costs and many others (Hua, 2009). The energy/thermal functions include energy usage, carbon emissions, thermal analysis, heating/cooling load evaluation and ventilation. The lighting and shading analysis includes solar analysis, daylighting assessment, and LEED Daylight Credit 8.1 feature. The value/cost analysis functions are included lifecycle assessment and lifecycle costs (Azhar *et al*., 2011).

2.3. GREEN BIM TECHNIQUES / BIM BASED SUSTAINABILITY ANALYSES

BIM softwares are typically involved in designing the basic BIM model of the building and exported it into BIM based analyses softwares or building simulation tools for sustainability analyses (Biswas, Wang, and Krishnamurthi, 2008). The techniques used in Green BIM tools are included energy/thermal analysis, lighting/shading analysis, acoustic, value and cost analysis (Motawa and Carter, 2013). Basic techniques included in Green BIM tools are summarized in Table 1 and following techniques are applicable up to the operation and maintenance phase of buildings.

Table 1: Green BIM Techniques

Green BIM Techniques/ Simulations	Features	Outcomes
Energy and Thermal Analyses	• Energy usage • Carbon emissions • Resource management • Thermal analysis • Heating/cooling loads • Ventilation and air flow • Heat loss calculations • Simulation of indirect environmental effects such as atmospheric pollutants associated with building energy use	• Energy use intensity • Renewable energy potential • Annual carbon emissions • Annual energy cost and consumption • Building heating and cooling loads • Breakdowns of energy use for major electric and gas components such as HVAC and lighting • Energy end use charts
Lighting and Shading Analysis	• Solar analysis • Day lighting assessment	• Calculations of solar energy absorption

	• Shading design analysis • Lighting design analysis • LEED daylight credit 8.1 • Radiance analysis	• Glare and discomfort spaces • Spaces where solar directly enters • Cooling and heating energy consumption • Solar orientations for the building
Value and Cost Analyses		• Life cycle assessment • Life cycle cost
Acoustic Analysis		• Noise dispersion and its effect inside the building
Water Harvesting		• Monthly non- potable water usage • Monthly potable water usage • Monthly water savings • Total water reuse potential • Building water demand • Rain water capture from the roof
Space Simulation		• Comparisons of alternative indoor air quality levels • Comparisons of alternative windows and shades • Dimensioning of air conditioning equipment • Analysis of temperature problems of the building
System Simulation		• Comparisons of alternative HVAC systems • Optimization of zones for AHUs • Dimensioning of cooling equipment based on actual cooling loads

(Source: Adapted from Azhar *et al*., 2011)

2.4. DATA REQUIRED FOR BIM TOOLS

The implementation of Green BIM technology for the existing green buildings basically depends over the availability of input data which are required to be included to the Green BIM tools. The preliminary input data required for Green BIM tools are identified as geometry data of the building. The geometry data of every individual component of the building envelope are needed for a detailed simulation (Wang, Choa and Kim, 2015). Further, simulation data need to be included for the tools for accurate sustainability analyses (Kim, Shen, Kim, Kim, and Yu, 2016). Bu, Shen and Anumba (2015) have mentioned, the typical inputs required for the simulation tools as building type, system types (HVAC), construction materials, project location (weather files) and room type (zone management). Moreover, Wang *et al*. (2015) have mentioned the input data including material properties, weather data, internal loads, operating strategy and schedules, HVAC systems and components and simulation specific parameters which should be incorporated to the building simulation tools. Some of the examples for geometry data could be mentioned as wall area, floor area, roof area, ceiling area, dimensions of doors and windows and any other specifications. The requirement of input data is depended upon the type of sustainability analysis/simulation and the Green BIM tool which provides each analysis. Data required for Green BIM techniques are shown in Figure 1.

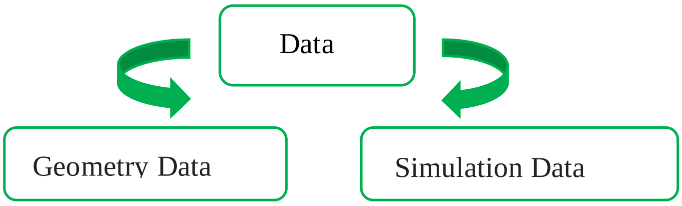

Figure 1: Green BIM Techniques

3. RESEARCH METHODOLOGY

The aim of the research was to identify the adaptability of Green BIM technology for the existing green buildings. Initially, through the literature review Green BIM tools, techniques and basic input data categories were determined. Even though, literature revealed the input data requirements as geometry data and simulation data, the types of data required under each category were not separately recognized and thus, types of input data had to be recognized through the data collection. To attain this, a desk study was first carried out to identify the input data requirements. Accordingly, desk study was undertaken using the published manuals of Green BIM tools. These manuals were included each data requirements separately for building geometry and simulation data categories. For collecting and analysing the identified data, content analysis was done using Nvivo 10 software.

The identified data were then subjected to a questionnaire survey to analyse the availability of data within the current LEED certified green buildings. The total population of forty LEED certified green buildings in Sri Lanka was considered for the analysis and availability of data was calculated as percentages under each building. The results showed that there is an acceptable level of data availability in buildings since the data were readily available through drawings and specifications. Nevertheless, it was required to further analyse the data availability to realize the required accuracy and reliability of data. Hence, a case study was conducted as a practical study for the research. The building with the highest data availability was selected for the case study and it was conducted by applying the Green BIM technology for the selected green building.

The application of this technology was mainly consisted with two stages as the creation of building model using basic BIM software and simulation of the created building model using BIM based sustainability software. These two stages were important to comprehend the accuracy and reliability of identified data for the appropriate application of Green BIM technology. Hence, within the application of Green BIM technology for the selected green building, basic BIM model of the building was needed to be created first, since BIM was not used for the design and construction phase of the building. Thus, the building was created with correspond to the electronic drawing of the building using Autodesk Revit BIM software.

Geometry data of electronic drawing were used to model the building due to convenience even though, both electronic and paper drawings were available. Within the process of creating the building model, it was realized that the geometry data of electronic drawing were not acceptably accurate since there were undesired errors due to inaccurate dimensions. Thus, the model was recreated using the paper drawing of the building since it was accurate as required. The actual building and its created BIM model is shown in Figure 2.

Figure 2: Actual Building and the Created BIM Model

After creating the model, it was exported to the Autodesk Green Building Studio from Revit, which was BIM based simulation software. Once the model is exported the geographical location of the building was specified for the energy simulations. The location data resulted with the information including latitude and longitude, altitude, city and state and time zone. The importance of location selection is to set the related climatic conditions and other related weather data, which affect to the entire building energy performance. After selecting the location, simulation data were entered to the GBS software including HVAC system types and efficiencies, lighting types and efficiencies, indoor temperatures, total occupancy, number of occupancy hours and operating schedules of the building systems, to run the simulations. The results obtained through the energy simulation are given in Table 2.

Table 2: Energy, Carbon and Cost Summary

Energy, Carbon and Cost Summary	
Annual Energy Cost	RS. 18,900,000
Life Cycle Cost	RS. 121,172,875.320
Annual CO^2 Emissions	
Electric	21.7 Mg
Onsite Fuel	85.2 Mg
Annual Energy	
Energy Use Intensity (EUI)	532 MJ/m2/Year
Electric	2,542,324 kWh
Fuel	359,124MJ/kg
Annual Peak Demand	10,800 KVA

Energy end use charts were further obtained from the GBS relating to the building cost (refer Figure 3).

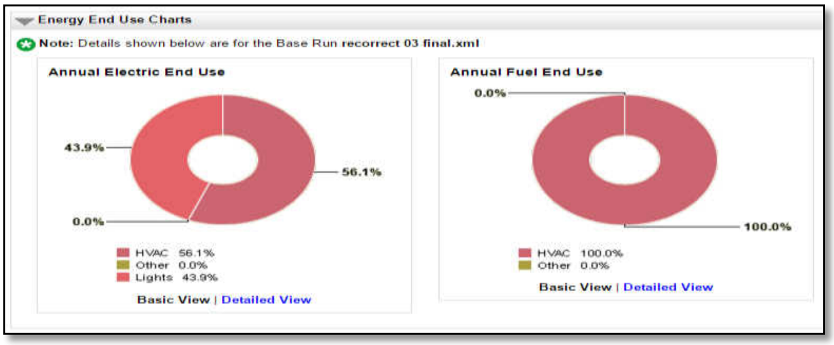

Figure 3: Energy End Use Charts

Monthly cost data of the building were also resulted by the simulation, relating to area lights (yellow), space cooling (dark blue) and vent fans (light blue) as shown in Figure 4.

Figure 4: Monthly Energy Cost Data

4. RESEARCH FINDINGS AND DISCUSSION

The results of the case study indicate that though BIM has not been utilized for the design and construction phases of the building, the Green BIM technology could successfully be implemented for the existing green buildings in Sri Lanka. According to the findings of the case study, Green BIM technology could be incorporated successfully to the existing green buildings, if the required input data are adequately and sufficiently available. Further, it was found that though data were available, the accuracy of data is needed to be considered to avoid the potential technical errors. The input data are basically important for both model creation and the simulation, but however literature findings did not review the types of required input data for the implementation of the technology.

As per the findings of the case study, the data availability with required accuracy and reliability is the critical requirement for the successful application of Green BIM technology. Thus, the effort of this research towards the implementation of Green BIM technology for an existing building within the non-existence of early utilized BIM, will make better opportunities to eliminate the hurdles of Green BIM usage for green building owners and practitioners.

5. CONCLUSIONS

Building Information Modelling (BIM) is an innovative technology and process which has quickly transformed the way of designing, constructing, analysing and managing the buildings. Green BIM technology is a part of BIM and a model-based process which undertakes generation and management of coordinated building data during the building life cycle, to improve energy performance of buildings while facilitating the accomplishment of sustainability goals. The integrated design information and collaboration of Green BIM, supports environmentally sustainable building development while reducing the adverse impacts to the environment. Though Green BIM is a well-known technology in today construction industry, it is seemed as an unprecedented concept in green building sector as its adaptation is less for existing buildings with compared to the new building constructions. Hence, it has been revealed that, the adoption rate of Green BIM for existing buildings is needed to be considered.

The aim of this research was to identify the potential of implementing Green BIM technology for the existing green buildings in Sri Lanka where BIM is not applied. According to the findings applicability of Green BIM technology is basically relied upon the availability of necessary data relating to the building design, construction and management. Utilization of Green BIM technology is more convenient in design and construction phases of buildings since all the data related to the building design and construction are readily available as required, with compared to an existing building. Hence, when it comes to an existing building, the implementation of Green BIM technology is highly depended upon the availability of drawings and specifications. Finally, it could be concluded that if the accurate data are available, Green BIM technology could successfully be implemented for the existing green buildings in Sri Lanka.

6. REFERENCES

Azhar, S., Brown, J. and Farooqui, R., 2009, April. BIM-based sustainability analysis: An evaluation of building performance analysis software. In: *45th ASC annual conference*, Gainesville, 1-4 April 2009 (Vol. 1, No. 4).

Azhar, S., Carlton, W.A., Olsen, D. and Ahmad, I., 2011. Building information modeling for sustainable design and LEED® rating analysis. *Automation in construction*, 20(2), 217-224.

Barbosa, M.J., Pauwels, P., Ferreira, V. and Mateus, L., 2016. Towards increased BIM usage for existing building interventions. *Structural Survey*, 34(2), 168-190.

Biswas, T., Wang, T.H. and Krishnamurti, R.A.M.E.S.H., 2008. Integrating sustainable building rating systems with building information models. *CAADRIA 2008*, 193-200.

Bu, S., Shen, G., Anumba, C.J., Wong, A.K. and Liang, X., 2015. Literature review of green retrofit design for commercial buildings with BIM implication. *Smart and Sustainable Built Environment*, 4(2), 188-214.

Cemesova, A., Hopfe, C.J. and Rezgui, Y., 2013. An approach to facilitating data exchange between BIM environments and a low energy design tool. In BS2013: 13th Conference of International Building Performance Simulation Association, 25–30 August 2013. Le Bourget Du Lac, France. (3234-3241).

Ghosh, A., Chasey, A. and Cribbs, J., 2015, BIM for retrofits: A case study of tool installation at an advanced technology facility. In: 51st ASC annual conference, 30 Sep 2015. Texas

Hua, G., 2009. A BIM based application to support Cost Feasible 'Green Building'concept decisions. *Handbook of Research on Building Information Modeling and Construction Informatics: Concepts and Technologies: Concepts and Technologies*, USA: IGI Global.

Jalaei, F. and Jrade, A., 2015. Integrating building information modeling (BIM) and LEED system at the conceptual design stage of sustainable buildings. *Sustainable Cities and Society*, 18, 95-107.

Kim, H., Shen, Z., Kim, I., Kim, K., Stumpf, A. and Yu, J., 2016. BIM IFC information mapping to building energy analysis (BEA) model with manually extended material information. *Automation in Construction*, 68, 183-193.

Krygiel, E. and Nies, B., 2008. *Green BIM: successful sustainable design with building information modeling*. Canada: John Wiley and Sons.

Moakher, E.P.E. and Pimplikar, S.S., 2012. Building information modeling (BIM) and sustainability–using design technology in energy efficient modeling. *IOSR Journal of Mechanical and Civil Engineering*, 1(2), 10-21.

Motawa, I. and Carter, K., 2013. Sustainable BIM-based evaluation of buildings. *Procedia-Social and Behavioral Sciences*, 74, 419-428.

Park, J., Park, J., Kim, J. and Kim, J., 2012. Building information modelling based energy performance assessment system: An assessment of the Energy Performance Index in Korea. *Construction Innovation*, 12(3), 335-354.

Redmond, A., Hore, A., Alshawi, M. and West, R., 2012. Exploring how information exchanges can be enhanced through Cloud BIM. *Automation in Construction*, 24, 175-183.

Richardson, G.R. and Lynes, J.K., 2007. Institutional motivations and barriers to the construction of green buildings on campus: A case study of the University of Waterloo, Ontario. *International Journal of Sustainability in Higher Education*, 8(3), 339-354.

Shoubi, M.V., Shoubi, M.V., Bagchi, A. and Barough, A.S., 2015. Reducing the operational energy demand in buildings using building information modeling tools and sustainability approaches. *Ain Shams Engineering Journal*, 6(1), 41-55.

Solla, M., Solla, M., Ismail, L.H. and Yunus, R., 2016. Investigation on the Potential of Integrating BIM into Green Building Assessment Tools. *ARPN Journal of Engineering and Applied Sciences*, 11(4), 2412-2418.

Tae, S., 2012. Study on evaluation of building energy efficiency rate using BIM based simulation tool. *World Journal of Engineering*, 9(3), 227-232.

Waidyasekara, K.G.A.S. and Fernando, W.N.J.K., 2013. Benefits of adopting green concept for construction of buildings in Sri Lanka. [Online]. Available from: http://www.civil.mrt.ac.lk/conference/ICSBE2012/SBE-12-174.pdf. [Accessed 19 June 2016]

Wang, C., Cho, Y.K. and Kim, C., 2015. Automatic BIM component extraction from point clouds of existing buildings for sustainability applications. *Automation in Construction*, 56, 1-13.

Wong, J.K.W. and Zhou, J., 2015. Enhancing environmental sustainability over building life cycles through green BIM: A review. *Automation in Construction*, 57, 156-165.

Wong, K.D. and Fan, Q., 2013. Building information modelling (BIM) for sustainable building design. *Facilities*, 31(3/4), 138-157.

Zanni, M.A., Soetanto, R. and Ruikar, K., 2014. Defining the sustainable building design process: methods for BIM execution planning in the UK. *International Journal of Energy Sector Management*, 8(4), 562-587.

ALCOHOL CONSUMPTION PATTERNS OF CONSTRUCTION WORKERS IN HONG KONG

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ABSTRACT

Alcohol consumption is prevalent among construction workers, and it may have negative implications for workers' overall health, productivity, and safety performance. The alcohol-related risks are associated with drinking pattern and consumption volume. To understand the drinking pattern and help devise effective interventions to prevent drinking problem in construction workers in Hong Kong, the research team conducted a one-month drinking pattern survey with a convenience sample of construction workers on railway projects in Hong Kong, using the Alcohol Use Disorders Identification Test (AUDIT) as the primary instrument. With 1203 valid responses, the research team compared alcohol-related risk exposure among different categories of workers through Chi-squared tests. The results showed that 16.6% of respondents drink excessively, and 28% drink in a harmful way. Furthermore, male workers are prone to more severe alcohol-related risks than their female counterparts, Nepalese workers are exposed to more severe alcohol-related risks than their Chinese counterparts, workers in four trades (i.e., mechanics, welders, shotfirers, and miners) are more likely to experience alcohol-related risks than others, and workers in the age group of 30-39 are subject to more severe alcohol-related risks. The findings can help regulatory bodies formulate industry-wide codes of practice and prompt management to give special attention to certain categories of workers.

Keywords: *Audit; Chi-squared Test; Construction Worker; Hong Kong.*

1. INTRODUCTION

Alcohol is the most widely used and misused psychoactive substance, which has the potential to impair cognitive and behavioural performance (Frone, 2006). Given the specific context, Frone (2004) distinguishes alcohol use and impairment off-the-job from on-the-job. Accordingly, Frone (2006) later on presents two (02) related concepts: alcohol use and impairment in the workforce and alcohol use in the workplace. Alcohol use and impairment in the workforce largely reflects use and impairment away from work and outside an individual's normal work hours, while alcohol use in the workplace represents impairment due to alcohol use during one's work hours.

Workplace alcohol use and impairment are prevalent, and construction workers are potentially at risk for workplace alcohol use and impairment. In the U.S., Frone (2006) draw a national probability sample of 2805 employees using a random digit dialling telephone survey, and explore the extent of alcohol use and impairment in the workplace. Workplace alcohol use and impairment was found to directly affect an estimated 15% of the U.S. workforce. In particular, the study found that an estimated 1.83% drink before work, 7.06% drink during the workday, 1.68% work under the influence of alcohol, and 9.23% work with a hangover. Furthermore, employees in the construction and extraction occupations were more likely to experience workplace alcohol use and impairment. In a similar vein, a review of alcoholism and occupations suggests a high prevalence of alcohol dependence and misuse in construction, and shows that more than one (01) in four (04) construction labourers and one (01) in five (05) skilled construction trade workers receives a diagnosis related to alcohol misuse (Mandellet *et al.*, 1992). In Australia, Biggs and Williamson (2013) also found that over half of those sampled in the construction sector are at risk of hazardous alcohol consumption. Mosconi *et al.* (2007) conducted a study on alcohol consumption and the consequences that alcohol abuse has on health,

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working ability, accidents and absenteeism in construction workers. They found that alcohol consumption during pauses in work is still common (Mosconi *et al.*, 2007). High alcohol consumption is also associated with long-term unemployment among middle-aged construction workers (Leino-Arjas *et al.*, 1999).

Alcohol use may pose a risk to employees' overall health, productivity and safety. Excessive drinking is definitely detrimental to health, although non-drinking pattern is not preferable either. With a cohort of male employees in the German construction industry, Brenner *et al.* (1997) founda very strong U-shaped relationship between alcohol consumption and all-cause mortality. In particular, they foundthat mortality was 2.8 times higher among non-drinkers than among men who consumed 1-49 g of alcohol per day, and strongly increased mortality among heavy drinkers. Alcohol is involved in a wide variety of diseases and disorders. It may cause liver cirrhosis, pancreatitis, hypertension, gastritis, diabetes, stroke, cancer of the mouth, cancer of the oesophagus and larynx. Alcohol-related diseases lead to work limitations or disability, and average consumption of alcohol is associated with accident frequency/seriousness and absenteeism (Mosconi *et al.*, 2007). Excessive drinking causes illness and distress, and accounts for breakdown in relationships, trauma, hospitalization, prolonged disability and early death (Baboret *et al.*, 2001).

Currently, there are few studies on the prevalence and risk of alcohol consumption among construction workers based in Hong Kong, let alone alcohol consumption on the job. This paper aims to reveal alcohol use and impairment in construction workers, i.e., to assess construction workers' overall use of and impairment from alcohol across all contexts. It reports the survey results and attempts to help understand construction workers' drinking behaviour.

2. RESEARCH METHOD

2.1. MEASURES

The Alcohol Use Disorders Identification Test (AUDIT) was used in the survey for two (02) reasons. First, it can provide an accurate measure of risk across gender, age, and cultures. Second, compared to other questionnaires, it is the best screening instrument for a whole range of alcohol problems in primary care (Babor *et al.*, 2001). The AUDIT was developed by the World Health Organization (WHO) to screen for excessive drinking and assist in brief assessment. It helps identify whether the person has hazardous (or risky) drinking, harmful drinking, or alcohol dependence. Hazardous drinking increases the risk of harmful consequences for the user or others. Harmful drinking causes harm to physical and mental health. Alcohol dependence refers to a cluster of behavioural, cognitive, and physiological phenomena, which may develop after repeated alcohol use (Babor *et al.*, 2001). In AUDIT, there are ten (10) questions, which are rated on a 5-point Likert scale (0-4). The cumulative score, therefore, ranges from zero (0) to forty (40). These ten (10) questions cover three (03) domains. The first three (03) questions, 1-3, identify hazardous alcohol use. The second three (03) questions, 4-6, identify alcohol dependence symptoms. The remaining four (04) questions, 7-10, indicate harmful alcohol use. Biggs and Williamson (2013) make some interpretations to the cumulative score in each domain. In the domain of hazardous alcohol use, the cumulative score of no less than six (6) indicates a risk of alcohol-related harm. In the domain of alcohol dependence symptoms, the cumulative score of no less than four (4) suggests possible alcohol dependence. In the domain of harmful alcohol use, any score deserves further investigation.

Furthermore, the AUDIT can provide an intervention framework to help risky drinkers reduce or cease alcohol use and hence avoid harmful consequences (Babor *et al.*, 2001). According to Babor *et al.* (2001), different ranges of the cumulative score correspond with different levels of alcohol-related risk. Currently, there are four (04) levels of risk. The first level, Level I, refers to low-risk drinking or abstinence, and is indicated by an AUDIT score between zero (0) and seven (7). At this level, the patients need alcohol education. The second level, Level II, indicates alcohol use in excess of low-risk guidelines (i.e. less than twenty (20) grams of alcohol per day, and less than six (6) days a week), and corresponds to a score between eight (8) and fifteen (15). At this level, the patients need simple advice and alcohol education. The third level, Level III, refers to harmful and hazardous drinking, and scores 16-19. Respondents at this level can be managed by a combination of simple advice, brief counselling and continued monitoring. If the respondents exhibit possible alcohol dependence, further diagnostic evaluation should be administered. The fourth level, Level IV, is indicated by an AUDIT score above nineteen (19). Respondents at this level should be referred to a specialist for diagnostic evaluation and possible treatment for alcohol dependence. Note that the AUDIT cut-off score may vary slightly depending on the country's drinking patterns, the alcohol content of standard drinks, and the nature of the screening program.

2.2. *Population and Sample*

The population was railway project construction workers based in Hong Kong. In cooperation with a local public utility service provider, the construction sites sampled in this study were selected based on their geographical location and the maximum number of workers accessible. In total, thirty-seven (37) construction sites involving forty-nine (49) contracts from five (05) railway projects were accessed. With assistance from the safety officer at each of the forty-nine (49) contracts, the research team approached all available construction workers on site during their pause at work. The workers were assured that their response was only for research purposes, would be kept confidential, and their participation was entirely voluntary. The survey last for a month and 1203 valid responses were obtained. Table 1 shows individual characteristics of the respondents.

Table 1: Individual Characteristics of the Respondents

Characteristics	Frequency	Percentage (%)
Gender		
Male	1015	84.4
Female	185	15.4
N.A.	3	0.2
Age (years)		
≤ 29	144	12
30 - 39	250	20.8
40 - 49	326	27.1
50 - 59	315	26.2
≥ 60	122	10.1
N.A.	46	3.8
Ethnicity		
Chinese	924	76.8
Nepalese	233	19.4
Pakistani	18	1.5
Other	22	1.8
N.A.	6	0.5
Trade		
Steel fixer	39	3.2
Shotfirer	18	1.5
Concreter	58	4.8
Rigger	59	4.9
Miner	31	2.6
Welder	60	5
Carpenter	69	5.7
Scaffolder	58	4.8
Electrical wireman	110	9.1
Leveler	86	7.1
Plasterer	14	1.2
Signal man	68	5.7
General worker	445	37
Machine operator	36	3
Mechanic	32	2.7
Surveyor	20	1.7
Role		
Worker	1093	90.9
Ganger	40	3.3
Foreman	45	3.7
N.A.	25	2.1

2.3. *DATA ANALYSIS*

According to responses to the AUDIT, respondents could be organised by four (04) categorical variables regarding drinking behaviour, i.e., hazardous drinking (yes/no), alcohol dependence (yes/no), harmful drinking (yes/no), and levels of alcohol-related risk (Level I, Level II, Level III, and Level IV). In addition, respondents can be categorized by another five (05) demographic variables, i.e., gender, age, ethnicity, trade, and role. Therefore, the research team decided to use chi-square tests to determine, whether there is association between respondents' drinking behaviour and individual characteristics.

3. RESEARCH FINDINGS

Overall, 81.5% of the respondents are subject to low-risk drinking and need alcohol education. 16.6% of the respondents drink excessively and need simple advice and alcohol education. 1.4% of the respondents are prone to hazardous and harmful drinking and need a combination of simple advice, brief counselling and continued monitoring. 0.5% of the respondents should be referred to a specialist for diagnostic evaluation and possible treatment for alcohol dependence. Figure 1 shows the distribution of respondents at different levels of alcohol-related risk. Furthermore, 12.8% of the respondents are drinking in a hazardous way, 3.4% of the respondents are experiencing alcohol dependence, and 28% of the respondents are drinking in a harmful way.

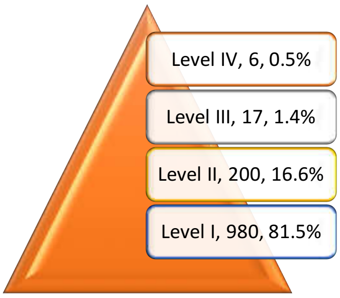

Figure 1: Distribution of Respondents at Different Levels of Alcohol-related Risk

In order to test, whether there is association between respondents' individual characteristics and drinking behaviour, the research team carried out Chi-square tests. The results of chi-square tests are shown in Table 2.

Visual inspection suggests that compared with their female counterparts, male construction workers are more likely to engage in hazardous drinking, alcohol dependence, harmful drinking, and hence are subject to higher levels of alcohol-related risk. The age group of 30-39 deserves more attention as they have more alcohol-related problems than other groups. Nepalese workers are exposed to more severe alcohol-related risks in comparison with their Chinese counterparts. Workers in ten (10) trades (i.e., steel fixers, concreters, miners, carpenters, scaffolders, electrical wiremen, levellers, signal men, machine operators, and mechanics) are more likely to experience alcohol-related risks than others.

It is interesting to find that there is no significant difference with regard to drinking behaviour and alcohol-related risk exposure among foremen, gangers and workers ($p > 0.05$).

Table 2: Results of Chi-square Tests

		Hazardous drinking		Alcohol dependence		Harmful drinking		Level of alcohol-related risks			
		Yes	No	Yes	No	Yes	No	Level I	Level II	Level III	Level IV
Gender	Male	153	862	41	974	326	689	794	198	17	6
	Female	1	184	0	185	11	174	183	2	0	0
Remark		$p < 0.05$		$p < 0.05$		$p < 0.05$		$p < 0.05$			
Age	≤ 29	30	114	7	137	47	97	113	29	1	1
	30—39	43	207	18	232	83	167	185	57	6	2
	40—49	40	286	7	319	91	235	271	48	5	2
	50—59	31	284	4	311	76	239	266	43	5	1
	≥ 60	4	118	1	121	22	100	111	11	0	0
Remark		$p < 0.05$		$p < 0.05$		$p < 0.05$		$p < 0.05$			
Ethnicity	Chinese	98	826	18	906	235	689	777	134	10	3
	Nepalese	51	182	20	213	92	141	166	59	6	2
	Pakistani	2	16	1	17	2	16	16	1	1	0
Remark		$p < 0.05$		$p < 0.05$		$p < 0.05$		$p < 0.05$			
Trade	Steel fixer	4	35	0	39	11	28	31	8	0	0
	Shotfirer	4	14	2	16	5	13	15	2	0	1
	Concreter	9	49	2	56	21	37	42	15	1	0
	Rigger	7	52	2	57	18	41	49	10	0	0
	Miner	9	22	3	28	15	16	18	11	2	0
	Welder	9	51	4	56	20	40	48	8	2	2
	Carpenter	14	55	1	68	25	44	53	15	1	0
	Scaffolder	11	47	4	54	21	37	43	14	1	0
	Electrical wireman	14	96	2	108	37	73	84	25	1	0
	Leveler	13	73	8	78	23	63	67	16	3	0
	Plasterer	2	12	0	14	4	10	11	3	0	0
	Signal man	8	60	2	66	21	47	55	13	0	0
	General worker	29	416	4	441	86	359	398	43	3	1
	Machine operator	10	26	1	35	7	29	28	8	0	0
	Mechanic	10	22	6	26	19	13	19	8	3	2
	Surveyor	1	19	0	20	4	16	19	1	0	0
Remark		$p < 0.05$		$p < 0.05$		$p < 0.05$		$p < 0.05$			
Role	Worker	136	957	37	1056	298	795	898	175	14	6
	Ganger	7	33	1	39	15	25	31	7	2	0
	Foreman	8	37	1	44	16	29	32	13	0	0
Remark		$p > 0.05$		$p > 0.05$		$p > 0.05$		$p > 0.05$			

4. DISCUSSION AND CONCLUSIONS

Excessive alcohol consumption has negative implications for construction workers' overall health, productivity, and safety performance. An open secret is that alcohol use in the workplace is rather prevalent among construction workers. However, currently there are few empirical studies on alcohol use and impairment in construction workers, let alone alcohol use on the job. Using the World Health Organization AUDIT, the research team carried out an alcohol consumption pattern survey with a convenience sample of railway project construction workers based in Hong Kong. The results show that alcohol consumption is prevalent in construction workers, despite the negative implications of alcohol use and impairment for employees' safety and productivity. 81.5% of the respondents engage in low-risk drinking and are in need of alcohol education. 16.6% of the respondents engage in excessive drinking and are in need of a combination of simple advice and alcohol education. 1.4% of the respondents engage in hazardous and harmful drinking and need a combination of simple advice, brief counselling and continued monitoring. 0.5% of the respondents should be referred to a specialist for diagnostic evaluation and possible treatment for alcohol dependence. Furthermore, 12.8% of the respondents are drinking in a hazardous way, 3.4% of the respondents are experiencing alcohol dependence, and 28% of the respondents are drinking in a harmful way.

The results of Chi-square tests suggest that construction workers' drinking patterns differ depending on their gender, ethnicity, age and trade. There seems to be no significant difference regarding drinking patterns among foremen, gangers, and workers.

Although this survey is about construction workers' drinking patterns off-the-job, it indicates that to reduce alcohol use on construction sites, efforts should be made in two (02) aspects: the work environment and the interventions. A work alienation/stress paradigm stands out among theories that account for workplace alcohol use (Frone, 1999). The paradigm views employee alcohol use as a direct or indirect response to physical and psychosocial qualities of the work environment. Therefore, creating an alcohol-free construction site needs upgrading both physical and psychological qualities of the site. A successful intervention is supposed to have six (06) elements, i.e., feedback of personal risk or impairment, emphasis on personal responsibility for change, clear advice to change, a menu of alternative change options, therapeutic empathy as a counselling style, and enhancement of client self-efficacy or optimism (Bienet *et al.*, 1993). Interventions that feature these six elements are supposed to be most effective.

No single procedure is universally suitable for early identification of harmful drinkers (Babor *et al.*, 1989). This research used self-report questionnaires as the primary screening tool, which may underestimate the prevalence of alcohol use among construction workers. This should be taken into account when interpreting the results. An alcohol-detection tool to test whether workers drink, such as breath alcohol sensor, may produce a more accurate estimate.

5. ACKNOWLEDGEMENT

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6. REFERENCES

Babor, T. F., Higgins-Biddle, J. C., Saunders, J. B., and Monteiro, M. G. 2001. *AUDIT: The Alcohol Use Disorders Identification Test: Guidelines for Use in Primary Care*. Geneva, Switzerland: World Health Organization.

Babor, T. F., Kranzler, H. R., and Lauerman, R. J. 1989. Early detection of harmful alcohol consumption: Comparison of clinical, laboratory, and self-report screening procedures. *Addictive Behaviours*, 14(2), 139-157.

Bien, T. H., Miller, W. R., and Tonigan, J. S. 1993. Brief interventions for alcohol problems: A review. *Addiction*, 88(3), 315-336.

Biggs, H. C., and Williamson, A. 2013. Alcohol and other drugs in the Australian construction industry: A pathway for safety focused cultural change. *In*:Kajewski, S. L., Manley, K., and Hampson, K. D.,eds. *19th CIB World Building Congress*, 5-9 May 2013Brisbane. Brisbane: Queensland University of Technology.

Brenner, H., Arndt, V., Rothenbacher, D., Schuberth, S., Fraisse, E., and Fliedner, T. M. 1997. The association between alcohol consumption and all-cause mortality in a cohort of male employees in the German construction industry. *International Journal of Epidemiology*, 26(1), 85-91.

Frone, M. R. 1999. Work stress and alcohol use. *Alcohol Research and Health*, 23(4), 284-291.

Frone, M. R. 2004. Alcohol, drugs, and workplace safety outcomes: A view from a general model of employee substance use and productivity. *In*: Barling, J. and Frone, M. R., eds. *The psychology of workplace safety*. Washington, D. C: American Psychological Association, 127-156.

Frone, M. R.2006. Prevalence and distribution of alcohol use and impairment in the workplace: A U.S. national survey. *Journal of Studies on Alcohol*, 67(1), 147-156.

Leino-Arjas, P., Liira, J., Mutanen, P., Malmivaara, A., and Matikainen, E. 1999. Predictors and consequences of unemployment among construction workers: Prospective cohort study. *British Medical Journal*, 319(7210), 600-605.

Mandell, W., Eaton, W. W., Anthony, J. C., and Garrison, R. 1992. Alcoholism and occupations: A review and analysis of 104 occupations. *Alcoholism: Clinical & Experimental Research*, 16, 734-746.

Mosconi, G., Riva, M. M., Lorenzi, S., Silva, G., Bartolozzi, F., Pavesi, G. and Magno, D. 2007. Alcohol and construction workers. *La Medicina del Lavoro*, 98(6), 493-500.

APPLICABILITY OF PHASE CHANGE MATERIALS (PCMS) FOR PEAK LOAD SHIFTING OF AIR CONDITIONING AND MECHANICAL VENTILATION (ACMV) SYSTEMS OF OFFICE BUILDINGS IN TROPICAL CLIMATES

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ABSTRACT

Air Conditioning and Mechanical Ventilation (ACMV) Systems are often used to maintain the thermal comfort and the indoor air quality in office buildings in tropical climates. These ACMVs usually account for more than 50% of the total energy consumption of the buildings. Compared to other available technologies, use of Phase Change Materials (PCMs) has been identified as an attractive innovative technology to reduce the peak cooling load and also to shift the peak cooling load to after office-hours. Temperature of building envelopes constructed using conventional materials such as bricks and concrete tend to vary with the surrounding environmental conditions, as they only absorb or release the sensible heat. On the contrary, PCMs can absorb or release much larger amount of thermal energy from/to the surrounding as latent heat, while maintaining the building envelope temperature unaffected under varying environmental conditions. Thus, conventional building envelopes accompanied with PCMs are able to significantly reduce the external heat gains into the conditioned spaces of the buildings, resulting a significant reduction in the peak cooling load. This study is mainly focused on exploring the applicability of PCMs for hot and humid tropical climates. Numerical analysis supported and validated by an experimental program and a case study revealed that by covering exterior of building envelop with 5 mm - 10 mm thick PCMs can reduce the building peak cooling load by 8% - 12%. Moreover, it was found that the peak cooling load could be easily shifted to after office hours by increasing the PCM thickness. Economic analysis showed that the PCMs with higher thermal cycles reduces the pay back periods up to 2 - 3 years and, further supported the use of low-temperature PCMs for building applications. Findings of this study recommend to incorporate the PCMs on the building envelops of the sunlit walls to reduce the peak cooling load of the building with the aim of reducing the energy consumption by the ACMV system.

Keywords: *Air Conditioning and Mechanical Ventilation (ACMV); Building Energy Consumption; Building Envelope; Peak Cooling Load; Phase Change Materials (PCMs).*

1. INTRODUCTION

Investigation of energy efficiency improvements in buildings has become one of the most significant research interests around the world today. The scarcity of natural resources, progressively increasing oil prices, carbon dioxide taxation, global warming potential and ozone depletion potential due to different materials used in building applications, make fuel economy related researches much relevant and compelling. Due to the urbanization, density of high rise buildings and sky scrapers rapidly increases and hence the use of Air Conditioning and Mechanical Ventilation (ACMV) systems are also heavily increased. ACMV systems are used to create the required thermal comfort and to provide fresh air for occupants maintaining indoor air quality. ASHRAE (American Society for Heating, Refrigeration and Air Conditioning Engineers) recommends to maintain 22°C - 27°C air temperature, 20% - 80% relative humidity and 0.25 m/s air velocity to ensure the indoor thermal comfort conditions for a hot, humid and tropical climate (ASHRAE Hand Book, 2013). As a result, more than half of the electrical energy used by a building, located in a hot and humid climate, is

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consumed by the ACMV system. According to Sri Lanka Energy Balance (2016), around 30% of total electricity consumption by the country is used for commercial sector and out of that more than 50% is used for ACMV systems; whereas, around 35% of the total electricity consumption is used for domestic sector, mainly for lighting.

Energy consumption by an ACMV system can be significantly reduced by minimizing the cooling load (or net heat gain), by optimizing the equipment selection and system design and also by introducing best practices to operate the system. Heat gain into the building can be reduced by controlling the conduction heat exchange between the building and the outside environment through walls, glazing and roof. This includes the reduction of excess ventilation, infiltration, solar radiation through fenestrations. Additionally, controlling the internal heat generation by occupants and equipment also helps to reduce the total cooling load. Intensity of heat gain due to conduction between the building and outdoor environment is highly dependent on the material properties of the building envelope.

Moreover, heat gain from conduction is immediately transferred to the room air by convection and the cooling load of the building is increased. On the contrary, heat gain by the radiation (i.e. sun and light sources) is first absorbed by the surfaces of the building. Then depending on the thermal capacities of the building envelopes, their temperature increases slowly due to absorption of radiant heat and is called 'heat storage effect'. As a result, radiation heat gains introduce a 'time lag' depending upon the surface characteristics and the heat capacity of the building envelops. Hence, total radiation heat gain by the building envelope does not immediately contribute to the cooling load of the building. Owing to this phenomenon, indoor and outdoor peak temperatures do not occur simultaneously and very often, indoor peak temperature occurs with a time delay which depends on the heat capacity of the building envelope.

In general, an office building is occupied from 8:30am to 4:30pm. Hence, power consumption by the ACMV system can be significantly reduced by shifting the peak cooling load and the peak temperature of the building to after office hours. This can be achieved by increasing the 'time lag' between the occurrences of peak indoor and outdoor temperatures. 'Time lag' can be increased by increasing the heat capacity (or heat storage effect) of the building. Therefore, this study focuses on investigating the possibilities of controlling the above time lag using Phase Change Materials (PCMs), with the aim of shifting the peak temperature and load to after office hours. To perform this, a numerical analysis on building heat gains and an economic analysis have been performed followed by a thorough review on PCM selection for building applications.

2. SELECTION OF PHASE CHANGE MATERIALS FOR BUILDING APPLICATIONS

2.1. THERMO-PHYSICAL PROPERTIES OF PHASE CHANGE MATERIALS

A substance which changes the phase when heated (or cooled) is referred to as a Phase Change Material. Solid PCMs are melted when heated and liquid PCMs are solidified when cooled. Moreover, heat is absorbed during melting and heat is released during solidification. Amount of heat absorbed by a solid PCM until it reaches to the melting temperature from a lower temperature is called the solid sensible heat. When the heat is further supplied to a solid PCM its phase is changed from solid to liquid while maintaining the temperature at the melting point (if pressure is unchanged). The heat required for the phase change is called the latent heat of melting. Once all the material is melted, if further heat is absorbed (liquid sensible heat), the temperature of the liquid material is increased until the start of next phase change (liquid to gas). The reverse process: solidification of a liquid PCM, also can be described in a similar way as shown in Figure 1. As a result, a PCM undergoes a thermal charging and discharging cycle, where it behaves as a sensible heat storage material and as well as a latent heat storage material.

One of the most important thermal properties of PCMs is to have high latent heat of fusion (melting) per unit volume (or weight) so that more heat can be absorbed (or released) for a small amount of PCM. In addition, selection of PCMs for a given application is temperature specific. To obtain the maximum use of PCMs, the phase change temperature must be in accordance with the climate, location and the application it is used. As a high thermal conductivity will allow heat to disperse through or leave a material more quickly (allowing the PCM to absorb or release heat at a higher rate), PCMs should have high thermal conductivities. To undergo many thermal charging and discharging cycles, thermal stability of PCMs should be very high and thermal properties should be reproducible during the entire life time. Moreover, the PCMs should be non-toxic, non-flammable, non-explosive and environmentally friendly. Also, they should be non-corrosive for some selected encapsulation materials (i.e. metal). Small volume change during solidification/melting is also essential to reduce the volume needed to encapsulation. The difference between the solidification and melting temperatures should be very low (preferably the same) and the irreversibility during the thermal cycles should be minimum to ensure the high efficiency of the entire process. More importantly, the selected PCM for a given application should be abundant and cheap, to obtain more economic benefits (Kalnaes, 2015).

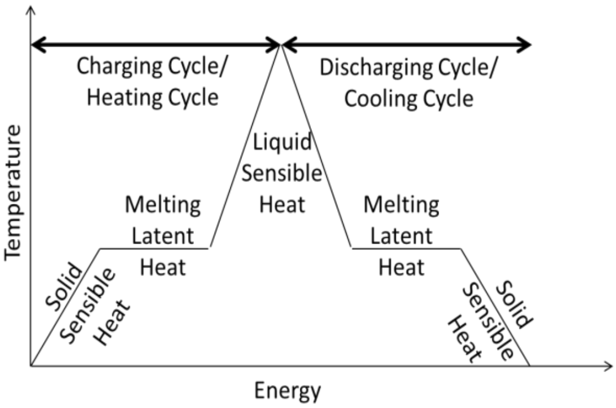


Figure 1: Thermal Cycle of a PCM
(Source: Sutterlin, 2016)

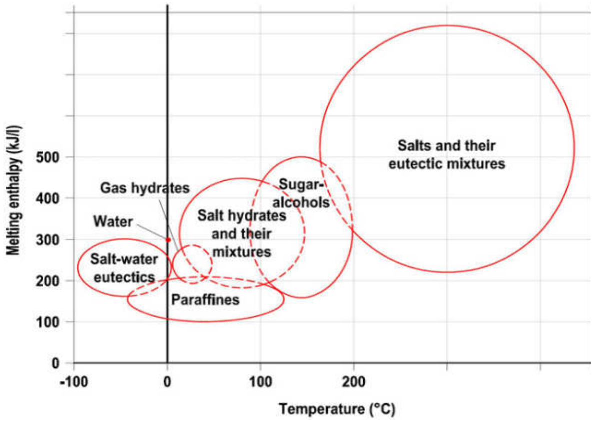


Figure 2: Melting Enthalpy and Meting
Temperature of Different PCMs
(Source: Baetens, 2010)

2.2. *TYPES OF PCMS*

PCMs can be divided into three main groups based on their chemical composition: organic compounds, inorganic compounds and eutectic mixtures (or inorganic eutectics). Organic PCMs are mainly grouped as paraffins and non-paraffins i.e. fatty acids, esters, alcohols and glycols. Organic PCMs are generally chemically stable, do not suffer from super-cooling, non-toxic and non-corrosive. As shown in Figure 2, paraffins demonstrate the lowest heat of fusion among all the other PCMs. They are more promising to be employed in building applications owing to the low melting temperatures which are in the human thermal comfort zone. On the other hand, non-paraffin PCMs have high latent heat of fusion. However, there is a lack of material which melts in the human comfort region. Moreover, cost of non-paraffin PCMs are about three times higher than the paraffins PCMs. So, paraffin PCMs can be identified as one of the candidate option for building application.

Most common inorganic PCMs are hydrated salts. In general, they have the highest heat of fusion, high melting temperatures, good thermal conductivity, non-flammable and are very cheap. As majority of these materials show super-cooling and phase segregation, they are more suitable for using as thermal energy storage medium rather than in building envelope applications. Eutectic mixtures are made of mixing multiple numbers of organic and/or inorganic PCMs to obtain the best performance depending on the application, yet they are still in the research and development state (Kalnaes, 2015 and Baetens, 2010).

2.3. *SELECTION OF PHASE CHANGE MATERIALS FOR TROPICAL CLIMATE*

Identifying the optimum phase change temperature for a given application is challenging as it governs the energy performances. Using some simplified heat transfer assumptions, Peippo et.al, (1991) obtained the following formulae to determine the average temperature of the conditioned space, optimum phase change temperature and the material thickness for PCMs.

$$T_{m,opt} = T_r + \frac{Q}{ht_{stor}} \qquad \text{(Eq: 01)}$$

$$D_{opt} = \frac{t_n h}{\rho \Delta H}\left(T_{m,opt} - T_n\right) \qquad \text{(Eq: 02)}$$

$$T_r = \frac{t_d T_d + t_n T_n}{t_d + t_n} \qquad \text{(Eq: 03)}$$

where, $T_{m,opt}$ = optimal phase change temperature of the PCM (°C), T_r = average temperature of the conditioned space (°C), Q = heat absorbed per unit area of the conditioned space (J/m2), h = average convection heat transfer coefficient between wall surface and the surroundings(W/m2.°C), T_d = daytime temperature of the conditioned space (°C), T_n = night time temperature of the conditioned space (°C), t_d = charging time, day (s), t_n = discharging time, night (s), $t_{stor} = t_d + t_n$, D_{opt} = optimum thickness of the PCM (m), ΔH = latent heat of fusion of the PCM (J/kg).

Office buildings in a tropical country like Sri Lanka operate from 8:30am - 4:30pm and are maintained at 25°C and 55%RH. If the average temperature in Colombo, during the after office hours is assumed to be 29°C, then the average conditioned space temperature was found to be 27°C. Solving above expressions, the optimum phase change temperature for the above conditions was found to be 30°C. It is very obvious that the optimum PCM temperature is highly depend on the operating temperature and time of the conditioned space.

Considering the temperature of fusion, feasibility of encapsulation, availability in the market and the price, paraffins was chosen to be used in this study. Table 1 shows some important thermo-physical properties of some selected paraffins based on (Seong, 2013) and (Thermal properties of RT35HC, 2016).

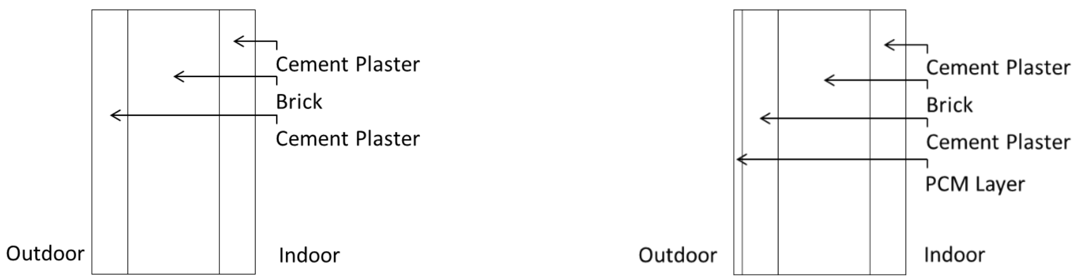
Table 1: Thermo-physical Properties of Some Paraffin PCMs

Property	**Dodecanol [Seong, 2013]**	**Octadecane [Seong, 2013]**	**RT35HC [Thermal Properties of RT35HC, 2016]**
Melting temperature (°C)	24	29	34
Conductivity (W/mK)	0.28	0.26	0.20
Density (kg/m^3)	853	777	800
Specific heat (kJ/kg.K)	1.55	1.20	2.00
Latent heat (kJ/kg)	230	235	240

3. HEAT TRANSFER ANALYSIS THROUGH BUILDING ENVELOPES

PCMs can be integrated to the building envelope at outside or inside the building wall and/or on the roof-slab of the building using PVC (polyvinyl chloride) panels or metals as encapsulations. When the PCMs are placed on the outside the building, it can reduce the heat gain into the building inner space during the day time due to the heat storage effect. On the other hand, when they are installed inside the building, it can make sure that it reduces the temperature fluctuations in the indoor environment. In addition, PCMs can be directly impregnated into porous building construction materials i.e. concrete, cement and plaster. However, this method may result leakage problems during phase change of the materials in the charging cycle. Microencapsulation has been proposed (Kuznik, 2011) to enclose the PCMs in a microscopic polymer capsule so that the encapsulated PCM powder can be mixed with other regular building construction materials. However, the encapsulation material should be carefully selected to make sure that no chemical reactions taken place with the other building materials. The volume expansion of the PCM has also to be carefully studied to make sure to minimize the crack propagation on the walls.

By analysing different integration methods as mentioned above, this study is performed assuming the tiled-PCM encapsulations are applied on the outside the building envelope to reduce the heat gain to the conditioned space as illustration in Figure 3. The equivalent thermal resistor networks for wall sections are shown in Figure 4.



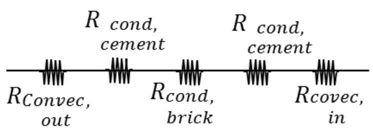


Figure 3: Building Envelope Without PCMs and Equivalent Resistance Network

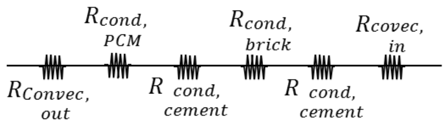


Figure 4: Building Envelop with PCMs and Equivalent Resistance Network

Thermo-physical properties of above materials and convection heat transfer coefficients of the indoor and outdoor environments are shown in Table 2.

Table 2: Thermo-physical Properties of Some Paraffin PCMs

Style Name	Conductivity (W/m.K)	Density (kg/m^3)	Specific Heat (J/kg.K)	Thickness (mm)	Convection (W/m^2.K)
Cement Plaster	1.50	1300	1550	20	
Brick	0.60	1800	900	200	
PCM	0.26	777	1200	10	
Indoor Convection Coefficient					10
Outdoor Convection Coefficient					15

Total thermal resistances without and with PCMs were calculated and are, 0.527 °C/W.m^2 and 0.565 °C/W.m^2 respectively. Increment of thermal resistance due to PCM layer was found to be 7.2% and hence, the thermal resistance due to PCM encapsulation material was neglected due to its very low thickness.

4. ANALYSIS ON BUILDING COOLING LOAD PROFILE

Cooling load analysis was performed for a 3-story office building located in Colombo. The internal partitions of the floors and different shading methods used to reduce the external heat gains were neglected. Approximate floor area of a floor is 700 m^2. Thermal resistance due to wall paint were also neglected. The doors were double glazed swing type (2 m x 2.5 m) having 20 mm air space sandwiched between two 5 mm thick clear glasses surrounded by 50 mm width Aluminium frame with thickness is 40 mm. Windows were single clear glazed (3 m x 1.5m) having 5 mm thick glass mounted on 40 mm width and 25 mm thick Aluminium frame.

Internal heat gain of a typical floor of the building is given in Table 3. It was further assumed for a new building which has Aluminium doors and windows, the infiltration losses are negligible and the required fresh air is delivered at a centralized AHU (Air Handling Unit). 5 mm thick PCM RT35HC (Table 1) was used to perform the numerical analysis where indoor thermal conditions were maintained at 25 °C and 55% RH. Finally, the cooling load profile of the floor for with and without PCMs was obtained as shown in Figure 5.

Table 3: Internal Heat Gains

	Power (W)	Number
Desktop computers	150	20
Laptop computers	60	40
Occupants (light office work)		
Sensible	75	40
Latent	35	40
Lighting (T8-Florescent)	32	50
Refrigerator	250	1
Water heater	2000	1
Laser printer	150	2
Photo copier	300	2

From the CLTD/CLF Cooling load analysis method (Cooling Load Temperature Difference/ Cooling Load Factor Method), it was found that the peak cooling load was reduced by around 8% - 9% and peak load has been shifted approximately by an hour compared to the outside maximum temperature.

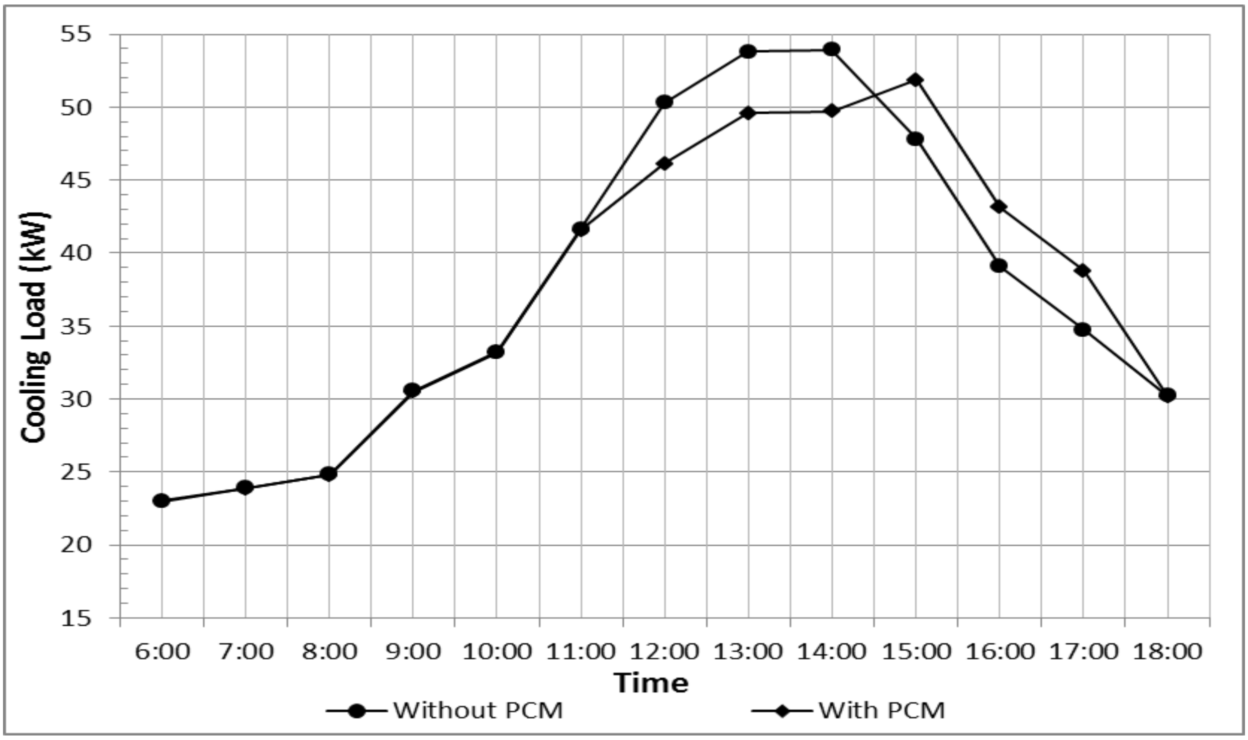


Figure 5: Cooling Load Profile of the Floor for with and without PCMs

5. Economic Analysis

Commercial paraffinic PCMs are made of by-products from the oil refineries and hence available abundant at a relatively cheaper price. Depending on the purity, pure paraffin wax (purity > 99%) is the most expensive paraffin and is approximately LKR 3000/kg (Kosny, 2013).

For the present work, PCM RT35HC (purity - 95%) (Thermal Properties of RT35HC, 2016) was used and the current market price is about LKR1800 per kg. The building considered here requires around 550 kg of PCMs to cover the entire sunlit walls, having an area of 145 m^2. It was also found that around 1-5 kW can be reduced from the peak cooling load resulting approximately 60 kWh of energy saving per day. If the life time of the PCM material is around 10,000 thermal cycles, it can last approximately 25 years assuming each day it experience a thermal cycle. If the unit price of the grid electricity is LKR 20, it was found that the payback period is around 4 years, considering only the cost involvement to purchase the phase change materials.

6. DISCUSSION

As explained above, PCMs can be used to reduce and shift the peak cooling load of a building to after hours of office buildings in tropical climates. Amount of heat absorbed by the building envelope can be reduced by increasing the material thicknesses of walls. Material thickness has to be selected based on an economic analysis as un-optimized selection would lead to higher payback periods. If the peak load is reduced, then the capacity of the entire AC system will be reduced and hence, initial investment would also be reduced, in addition to the running expenses. Therefore, attractive payback periods can be obtained by implementing PCMs in building wall-envelope application.

7. FUTURE WORK

Results of the numerical analysis will be validated by an experimental program and a whole building simulation using 'e-Quest' Software. Fabrication of the experimental test rig has already started and expected to obtain the results to validate the modelling work. A CFD analysis will also be performed to understand the transient thermal characteristics of the building envelope when integrated with PCMs.

8. REFERENCES

American Society of Heating, Refrigerating and Air-Conditioning Engineers. 2013. 2013 *ASHRAE handbook fundamentals*. [Online]. Available from:http://app.knovel.com/hotlink/toc/id:kpASHRAEC1/2013-ashrae-handbook. [Accessed 25 June 2016]

Baetens, R., Jelle, B.P. and Gustavsen, A., 2010. Phase change materials for building applications: a state-of-the-art review. *Energy and Buildings*, 42(9), 1361-1368.

Kalnæs, S.E. and Jelle, B.P., 2015. Phase change materials and products for building applications: a state-of-the-art review and future research opportunities. *Energy and Buildings*, 94, 150-176.

Kośny, J., Shukla, N. and Fallahi, A., 2013. Cost analysis of simple phase change material-enhanced building envelopes in southern US climates. US Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Program.

Kuznik, F., David, D., Johannes, K. and Roux, J.J., 2011. A review on phase change materials integrated in building walls. *Renewable and Sustainable Energy Reviews*, 15(1), 379-391.

Peippo, K., Kauranen, P. and Lund, P.D., 1991. A multicomponent PCM wall optimized for passive solar heating. *Energy and buildings*, 17(4), 259-270.

Rubitherm Technologies GmbH, 2016. *Thermal Properties of RT35HC, Specifications Manual*, [Online]. Available from: https://www.rubitherm.eu/ [Accessed 15 Nov 2016]

Seong, Y.B. and Lim, J.H., 2013. Energy saving potentials of phase change materials applied to lightweight building envelopes. *Energies*, 6(10), 5219-5230.

Sri Lanka Sustainable Energy authority, 2014, *'Sri Lanka Energy Balance'*. [Online]. Available from: www.info.energy.gov.lk. [Accessed 01 June 2016]

Sutterlin, W.R. 2016. *'Phase Change Materials, a Brief Comparison of Ice Packs, Salts, Paraffins and Vegetable- derived Phase Change Materials'*. [Online]. Available from: http://www.pharmoutsourcing.com/Featured-Articles/37854/. [Accessed 15 Nov 2016]

APPLICATION OF CLIENT'S QUANTITY SURVEYING PRACTICES IN THE POWER SECTOR IN SRI LANKA

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ABSTRACT

The effective use of Quantity Surveying practices is vital for the construction sector and its contribution to the overall economic growth and development of the country. With today's competitive economy, the profession has been identified as paramount in a broad range of development sectors. In Sri Lanka, Quantity Surveyors' involvement is limited to the construction stage of power generation and distribution projects as Consultant's Quantity Surveying and Contractor's Quantity Surveying practices. With the amplification of the power sector, cost and time overruns have been identified in power generation and distribution projects due to the absence of cost plans and the poor documentation of bids and contracts, leading to disputes, legal costs and poor administration of projects. Therefore, the involvement of Client's Quantity Surveyors in power sector projects has been identified as important. This is an emerging path for Quantity Surveyors to contribute their expertise in Sri Lankan public sector developments projects. In this context, the study investigated the applicability of client's quantity surveying practices in the Sri Lankan power sector. A mix research approach was adopted in the study including a preliminary survey and a questionnaire survey. The findings of preliminary survey were analyzed with content analysis technique. Data collected through questionnaire survey were analyzed using Relative Importance Index. It was identified that non-involvement of client's Quantity surveyors in the Sri Lankan power sector is due to the lack of recognition of the requirement of the profession in the sector and execution of duties demanding quantity surveying expertise by other professionals in the power sector.

Keywords: *Client's Quantity Surveyor; Power Sector; Quantity Surveying.*

1. INTRODUCTION

Quantity surveying as a profession offers services to clients in the construction industry (Udo and Abialo, 2015). Being an eminent profession in the construction industry, it adds value to the contractual and financial management of construction projects in all its stages (Dada & Jagboro, 2012). Once the Quantity Surveyor (QS) has been employed or commissioned by a client, he turns considerable expertise to ensure that the client gets full value for money (Wirepa, 2001).

Badu and Amoah (2004) argues that a QS is a professional in the construction industry who has the ability to analyse both cost components and physical construction works of a project in a successful way so as to be able to apply the results of his analysis in solving problems peculiar to each project. QSs work in conjunction with architects, consulting engineers and contractors safeguarding the client's interests as an independent professional with specialist skills for several centuries (Olanrewaju and Anahwe, 2015). However, the role of the QS is currently more vital than when it was originally established in England in 1785 and largely developed over the 19th century (Opawole *et al.*, 2012).

The origin of quantity surveying in Sri Lanka can be traced back to the British era. British QSs were employed during colonial period in the Public Works Department of Sri Lanka. However, during the World War II, these QSs left the country. Thereafter, Sri Lankans who had the opportunity of obtaining foreign education returned to the country and practiced as QSs (Rameezdeen & Jeyamathan, 2006). The quantity surveying profession is currently regarded as one of the well paid professions within the construction industry. The dynamic nature of the profession shapes up the skills and the competencies of the profession to cater timely demand (Thayaparan

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et al., 2011). There is a new optimism about the future of the quantity surveying profession and QSs are now seen as key players in the construction industry (Reddy, 2015).

Due to the changes in the professional structure with multidisciplinary working and the increased emphasis on continuing professional development, research and development regarding the profession of quantity surveying will play an important role the future, to apply quantity surveying expertise to new segments of construction industry (Ashworth *et al.*, 2013).

According to Ashworth, Hogg, and Higgs (2013), building work, building engineering services, civil engineering, heavy and industrial engineering are the four main areas that QSs are involved in the construction industry. QS's role is significant in industrial construction due to its changing circumstances and a greater emphasis to be placed for value for money. Works in heavy and industrial engineering includes onshore and offshore oil and gas projects, petrochemical projects, nuclear reprocessing and production facilities, process engineering projects, power stations and steel plants.

QSs are already involved in the power sector for a greater number of years in Sri Lanka, but it is limited to the construction stage of power generation and distribution in both Consultant's and Contractor's teams. Nevertheless, it has not been widened to the client QS's practices in the level of initiation of new power generation and distribution projects, maintenance activities. It can be observed that lack of involvement of client's QSs has led to a range of issues such as cost overruns due to the absence of cost plans, bills of quantities, and schedules of activities, and to disputes and legal costs driven by faulty contract documents. Therefore, the client's QS in the power sector has been identified as an emerging path where quantity surveying expertise can be incorporated in Sri Lankan public sector development projects.

Moreover, there are no studies conducted to explore the need of client's quantity surveying practices in Sri Lankan power sector. Addressing this gap and acknowledging the requirement of client's QSs in Sri Lankan power sector, this study investigated the applicability of client's quantity surveying practices in the Sri Lankan power sector.

2. LITERATURE FINDINGS

2.1. ROLE OF THE QUANTITY SURVEYOR

The QS has the utmost responsibility to address the key cost, financial and contractual issues of the construction process, which is always highly influenced by the environmental parameters, which are very sensitive to changes and are unique for every project, being one of the key professional experts in the construction (Senaratne & Sabesan, 2010). Traditionally, QSs have fulfilled the function of financial and contract controller of projects (Baloyi & Price, 2003).

According to Olatunde (2006), QSs are mostly involved with measuring and valuing of construction work being carried out under a construction contract where architect drawing are handed over to them to advise on likely costs, prepare tender documents, itemize the work to be carried out, negotiate construction contracts, value work as it proceeds and prepare final accounts which can be briefly described as a measure and value system. Moss (2004), describes the contemporary role of the QS as a 'client advocate and representative', who is proficient in construction design and economics, planning and procurement, administration and management, and project management. However, the quantity surveying profession has endeavored to broaden the role of QSs to include inter alia, project management, and facilities management in recent years (Crafford & Smallwood, 2007).

Within its contemporary role, QSs undertake a spectrum of work ranging from providing investment appraisals to construction project management (Hore *et al.*, 2009). The key role of the QS involved in the public sector is to control the public money on the way they are spent, by involving in projects of wider range of size along with maintenance and repair programs (Willis *et al.*, 1994). Therefore, QSs have realised that the acquisition of a more extensive skills set enables them to deliver greater benefits to clients, which may, in turn, lead to more work (Fanous, 2012). The technical skills possessed by QSs will not go any further without the support of soft skills (Frei *et al.*, 2013).

2.2. POWER SECTOR IN SRI LANKA

The electricity sector is dominated by the state-owned Ceylon Electricity Board (CEB) while other government and private sector organisations also have active involvements in different segments of the sector such as electricity generation and distribution in the electricity (Sri Lanka Sustainable Energy Authority, 2007). According to Energy Forum Guarantee Ltd (2006), it is currently undergoing a severe financial crisis. The root cause for this financial crisis is high generation cost of electricity. Despite being a country with one of the highest electricity tariff in the region, the CEB is not in position to recover this high generation cost. The Government envisages reaching a 100% target in country-wide electrification by 2015 (Ministry of Power and Energy, 2015). The growing electricity demand could be met only by adding adequate generation capacities, employing the most appropriate technologies in the most economical manner by supporting the long-term goals which includes increasing efficiency, quality of service and enhancing technical standards and safety of electricity industry in Sri Lanka (Asian Development Bank, 2015).

QS, identified as the cost manager, plays a critical role ensuring that clients gain value for the invested money in projects. The changes involved in the modern Quantity Surveying practices have and are resulting in adding great values to projects across different industries. Therefore, Sri Lankan power sector client requires QSs in their future projects to gain maximum value for money, effort and resources.

3. RESEARCH METHODOLOGY

A mix research approach was adopted which is a combination of both qualitative and quantitative approaches used together to eliminate drawbacks of both. Due to the unavailability of client’s quantity surveying practices in the power sector in Sri Lanka, a preliminary survey was carried out to collect qualitative data and a questionnaire survey was carried out to collect quantitative data.

Preliminary survey was carried out using an online questionnaire among six QSs working abroad, where QSs are attached to power sector as client’s professional. Survey findings ascertained the responsibilities of client’s QSs in the power sector, and the skills and competencies require by them. Code-based content analysis technique with NVivo software was adopted to analyze the findings of preliminary survey. Collected information were used for developing the questionnaire.

In the questionnaire survey, the respondents had to rate relevancy of identified responsibilities of the QSs within their own role and frequency of partaking in them. Forty-three (43) responses from professionals involved in the Sri Lankan power sector were collected through questionnaire survey and were analyzed by calculating the relative importance index for the relevancy and frequency of responsibilities, and were ranked accordingly.

4. RESEARCH FINDINGS

4.1. RESPONDENT’S PROFILE

The preliminary survey identified 33 number of responsibilities of a client’s QS in the power sector. Figures 1 and 2 show the content distribution of 43 respondents involved in the questionnaire survey according to the type of the organisation and working experience.

Among 43 respondents, a majority of respondents represents Ceylon Electricity Board (CEB) amount to 58% of the sample, followed by respondents representing Lanka Electricity Company Private Limited (LECO) and other power sector organisations amount to 28% and 14% respectively. This clearly shows that more than half of the respondents are from CEB which represents the monopoly of power sector in Sri Lanka while less than half of the sample consists of both LECO and other organisations.

As presented in Figure 2, 46% of the respondents have working experience between 21 to 25 years, 19% of the respondents have 16 to 20 years of experience, 5% of the respondents have 11 to 15 years of experience, 23% of the respondents have 5 to 10 years of experience and 7% have less than 5 years of experience. Since 70% of the respondents, who represents nearly three forth of the respondents, are experienced more than 10 years that help to establish the validity and relevancy of research outcome.

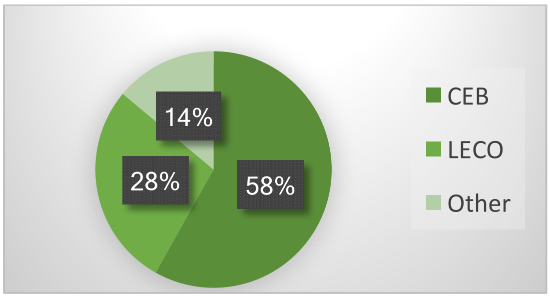

Figure 1: Respondents' Type of Organization

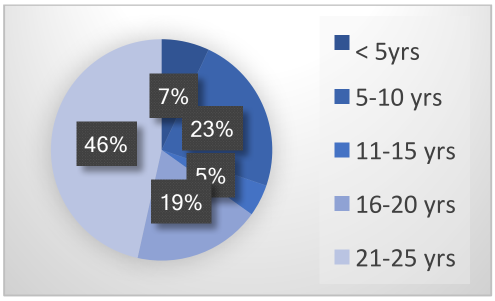

Figure 2: Respondents' Working Experience

Since most of the quantity surveying responsibilities are performed by professionals currently working in the power sector, it was required to consider their area of specialisation to identify whether they are competent enough to perform these responsibilities. However, questionnaire survey findings revealed that none of the professionals are specialised in quantity surveying discipline as depicted in Figure 3. Further it demonstrates that 91% of the respondents were from Electrical Engineering discipline and the balance 9% is from Civil Engineering discipline.

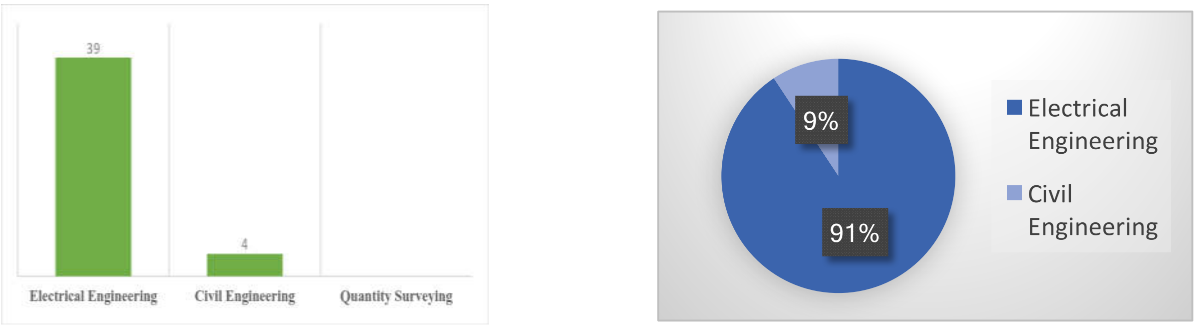

Figure 3: Composition of Area of Specialisation of Respondents

As shown in Figure 4, the designation of the majority of the respondents are Electrical Engineers.

Out of 43 respondents, 16 were Electrical Engineers and 13 were Chief Engineers. Among the others were Electrical Superintendents (02), Civil Engineers (04), Deputy General Managers (05) and one Engineering Assistant.

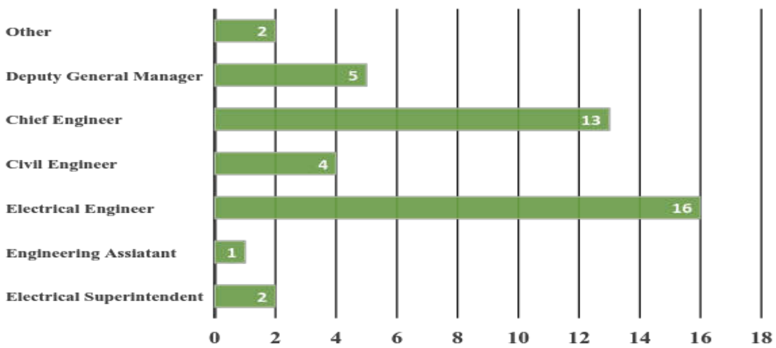

Figure 4: Composition of Respondents' Designation

Ultimately, it's evident from the above depictions that each cluster of the different profile holds a significant proportion to ensure the reliability of information obtained through this survey. Since it's a questionnaire survey to establish the requirement of QSs in power sector majority of the inputs have been collected from experienced respondents in the field of power generation and distribution.

4.2. *PRE-CONSTRUCTION DUTIES*

Table 1 shows the ranking of those pre-construction responsibilities by power sector professionals according to the relevancy of responsibilities within respondents' own role and frequency of involving in them.

Table 1: Ranking of Pre-Construction Responsibilities According to Relevancy and Frequency

No.	Responsibility	Relevancy Level			Frequency Level		
		MR	RII	Rank*	MR	RII	Rank*
1.	Preparation of Tender and Contract documents	4.12	0.824	2	3.54	0.708	3
15.	Tender evaluation	4.02	0.805	3	3.46	0.692	4
2.	Selection of contractors and subcontractors	3.90	0.781	4	3.22	0.643	5
29.	Ensure the budget is always secure with the design	3.74	0.748	6	3.14	0.627	6
9.	Effective contract negotiation	3.52	0.705	10	2.92	0.584	13
4.	Preparation of cost estimates	3.45	0.690	12	3.03	0.605	9
28.	Feasibility studies	3.36	0.671	15	2.81	0.562	16
5.	Handling cost data and cost advising	3.31	0.662	16	2.65	0.530	20
8.	Budgeting and cash flow forecasting	3.31	0.662	17	3.03	0.605	11
3.	Preparation of pre tender estimates	3.17	0.633	18	2.68	0.535	19
10.	Capturing and valuing cost associated with requirements (Preparation of Rates)	2.98	0.595	24	2.24	0.449	32
12.	Contingency and risk margin allocation	2.98	0.595	25	2.38	0.476	29
14.	Prediction of market trends and their impacts on proposed project	2.67	0.533	30	2.22	0.443	33
31.	Secure the expected profit margin	2.64	0.529	31	2.32	0.465	30

Note: MR – Mean Rating; RII – Relative Importance Index

**Please note that 1 is a lower rank and 2 is an upper rank comparatively*.

According to the ranking of pre-construction responsibilities, they are scattered from first ranks to final ranks in both relevancy and frequency distributions, though, nearly similar ranks are obtained by responsibilities for both relevancy and frequency. Preparation of Tender and Contract documents (1), Tender evaluation (15), Selection of contractors and subcontractors (2) and Ensure the budget is always secure with the design (29) are the responsibilities which are more relevant with power sector professionals' job role and carried out more frequently. Among them, Preparation of Tender and Contract documents (1) and Tender evaluation (15) were rated as highly relevant and most frequently carried out. Therefore, those responsibilities can be assumed as core duties in pre-construction stage of a Clients' QS, if QSs participate in power sector as a client's professional.

Capturing and valuing cost associated with requirements (10), Contingency and risk margin allocation (12), Prediction of market trends and their impacts on proposed project (14) and Secure the expected profit margin (31) are scattered in lower division of relevancy and frequency. Thus, Prediction of market trends and their impacts on proposed project (14) and Secure the expected profit margin (31) shows lowest relevancy and frequency.

Responsibilities budgeting and cash flow forecasting and securing the expected profit margin have got comparatively lower ranks for frequency with upper for relevancy, due to participation in those responsibilities frequently, even they are not very relevant in their job role. Thus, those can be considered more important duties for a Client's QS when they are attached to the Sri Lankan power sector.

4.3. *CONSTRUCTION DUTIES*

Table 2 illustrates the ranking of those construction responsibilities of power sector professionals according to the relevancy of responsibilities within respondents' own role and frequency of involving in them.

Table 2: Ranking of Construction Responsibilities According to Relevancy and Frequency

No.	Responsibility	Relevancy Level			Frequency Level		
		MR	RII	Rank	MR	RII	Rank
33.	Progress reviewing and updating/ Participation for progress meetings	4.14	0.829	1	3.78	0.757	1
22.	Record keeping of works	3.76	0.752	5	3.73	0.746	2
13.	Contract administration	3.71	0.743	7	3.08	0.616	8
6.	Scope change and variation management of works	3.57	0.714	9	2.78	0.557	17
17.	Interim valuation and payments	3.50	0.700	11	3.11	0.622	7
26.	Conflict management, negotiations and dispute resolution	3.45	0.690	13	2.89	0.578	15
32.	Control the changes arising to initial design by incorporating change control procedures	3.10	0.619	20	2.59	0.519	23
27.	Arbitration/ dispute resolution	3.10	0.619	21	2.51	0.503	26
16.	Cost accounting and control	3.05	0.610	22	2.65	0.530	21
7.	Cash flow monitoring and reporting	2.98	0.595	23	2.59	0.519	24
20.	Handling insurance and bonding	2.86	0.571	26	2.43	0.486	28
11.	Reconciling cost estimates with onsite cost realities	2.86	0.571	27	2.57	0.514	25
30.	Advice the design team time to time by doing cost plans where the cost limit or cost targets are exceeding than as planned	2.86	0.571	28	2.62	0.524	22
19.	Subcontract management	2.45	0.490	33	2.70	0.541	18

Note: MR – Mean Rating; RII – Relative Importance Index

**Please note that 1 is a lower rank and 2 is an upper rank comparatively.*

Construction responsibilities show a similar behaviour as pre-construction responsibilities by distributing within upper ranks to lower ranks. Progress reviewing and updating/ Participation for progress meetings (33), Record keeping of works (22), Contract administration (13) and Interim valuation and payments (17) are the construction responsibilities higher rating in both relevancy and frequency. Therefore, these can be assumed as core responsibilities of a Client's QS in power sector. Progress reviewing and updating/ Participation for progress meetings (33) and Record keeping of works (22) are highly relevant and carried out more frequently by power sector professionals.

Further, Cash flow monitoring and reporting (7), Handling insurance and bonding (20), Reconciling cost estimates with onsite cost realities (11), Advice the design team time to time by doing cost plans where the cost limit or cost targets are exceeding than as planned (30) and Subcontract management (19) are the responsibilities with lower relevancy and frequency. But, they are also scattered near the margin of three of Mean Rating. Though they show lower relevancy and frequency, they are somewhat relevant and somewhat frequently carried out by power sector client's professionals.

Record keeping of works, interim valuations and payments, cost accounting and controlling, reconciling cost estimates with onsite cost realities, advising the design team time to time by doing cost plans where the cost limit or cost targets are exceeding than as planned and subcontract management duties are done more frequently, though, they are not much relevant to the responsibilities of power sector professionals.

4.4. POST CONSTRUCTION DUTIES

Table 3 shows the ranking of those post-construction responsibilities by power sector professionals according to the relevancy of responsibilities within respondents' own role and frequency of involving in them.

Table 3: Ranking of Post Construction Responsibilities According to Relevancy and Frequency

No.	Responsibility	Relevancy Level			Frequency Level		
		MR	RII	Rank	MR	RII	Rank
23.	Management of defects rectification liability	3.69	0.738	8	3.00	0.600	12
25.	Obtaining practical/ final completions and Code Compliance Certificates	3.43	0.686	14	3.03	0.605	10
24.	Agreeing final accounts	3.14	0.629	19	2.92	0.584	14
21.	Handling liquidated and ascertained damages	2.79	0.557	29	2.49	0.497	27
18.	Cost analysis/ Cost modelling	2.55	0.510	32	2.30	0.459	31

Note: MR – Mean Rating; RII – Relative Importance Index

**Please note that 1 is a lower rank and 2 is an upper rank comparatively.*

Identified post construction responsibilities are less in number, thus, most of them are distributed in middle ranking of both relevancy and frequency rankings which is three of Mean Rating. Obtaining practical/ final completions and Code Compliance Certificates (25) shows more relevancy and frequency, the code compliance can be considered as a necessary requirement in the power sector. Handling liquidated and ascertained damages (21) and Cost analysis/ Cost modelling (18) shows less relevancy and also less frequency.

Responsibilities obtaining practical/ final completions and Code Compliance Certificates, agreeing final accounts, handling liquidated and ascertained damages and cost analysis/ cost modelling show lower ranking in frequency than relevancy which can be considered as supportive responsibilities to the core functions of a Client's QS within power sector.

4.5. *COMPARISON OF RELEVANCY VS. FREQUENCY OF RESPONSIBILITIES*

Figure 5 demonstrates the distribution of responsibilities considering their mean rating for relevancy and frequency. Responsibilities are numbered according to the numbering given in above tables. It can be observed that there are no responsibilities with low relevancy but high frequency.

Most of the responsibilities (13 out of 33) are distributed within higher relevancy and higher frequency area. 11 responsibilities are in higher relevancy lower frequency area, which are to be considered as the responsibilities that should be included in Client's QS's job role such as Feasibility studies (28) inclusive of life cycle costing. There are 9 responsibilities in lower relevancy lower frequency area, i.e. Prediction of market trends and their impacts on proposed project (14) and Secure the expected profit margin (31) shows lowest relevancy and frequency which may have led to cost and time overruns as identified in the research problem. However, this matrix plot will be useful in defining Client's QS's role within the power sector.

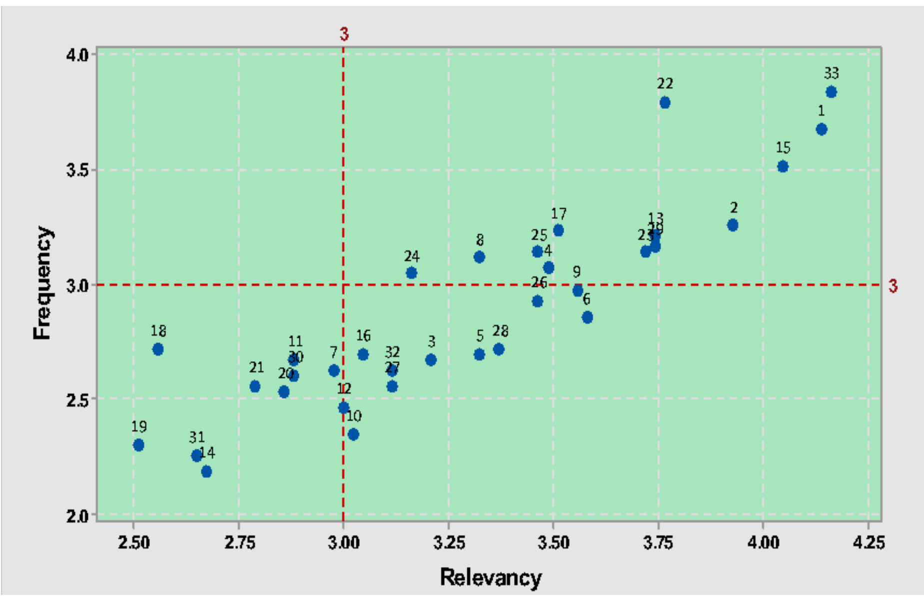

Figure 5: Matrix Plot of Relevancy vs. Frequency

5. CONCLUSIONS

This study has enclosed QSs having his/her professional practice in power sector. Analysis on research findings acknowledged the importance of QSs to involve in Sri Lankan power sector. Since the information revealed through literature is lacking to achieve the research objectives, a preliminary survey was conducted among QSs who are working in the power sector abroad. Accordingly, research findings from the questionnaire survey provided objective evidence for the data identified through the literature and collected through preliminary survey. This created a triangular effect between literature findings together with preliminary survey and questionnaire survey to make the data more reliable and valid.

Subsequently the profession of Quantity Surveying has widespread to many sectors with their expertise knowledge on cost management, Sri Lankan power sector operating within the government monopoly, is identified as a potential segment of new entrance for QSs. Questionnaire survey conducted identified the relevance of QSs in the power sector. Most of the duties performed by QS are conducted frequently by power sector professionals such as Electrical Engineers though their area of specification is not related to QS practices. In respondent profiles' there were no QSs involved but a few number of Civil Engineers. Their area of specialization also restricted to Electrical Engineering, where it can be concluded that if a QS expects to practice in power sector he would require to gain specific knowledge on Electrical Engineering, at least the basic concepts.

Moreover, from research findings it can be identified that the potential responsibilities of a Client's QS in power sector to be attached to his job role are the responsibilities that got lower ranking in frequency, but upper rank in relevancy as they are the responsibilities that are important for power sector clients but not relevant to current professionals. Eventually, it can be concluded that the profession of Quantity Surveying is important in Sri Lankan power sector within client practices.

There are several barriers for QSs to enter into power sector, such as being a specified field there are deviations of characteristics of construction methods, materials, and equipment from the construction industry causing QSs to acquire technical knowledge. Therefore, it is recommended to adhere electrical specific knowledge to the syllabuses of higher education institutes generating professional QSs.

6. REFERENCES

Ashworth, A., Hogg, K. and Higgs C., 2013. *Will's Practice and Procedure for The Quantity Surveyors*. 13th ed. UK: John Wiley and Sons Ltd.

Asian Development Bank, 2015. *Assement of Power Sector Reforms in Sri Lanka: Country Report.* 1st ed. Manila: Asian Development Bank.

Badu, E. and Amoah, P., 2004. Quantity Surveying Education in Ghana. Available from https://www.researchgate.net/publication /242252619_QUANTITY_ SURVEYING_EDUCATION_IN_GHANA [Accessed 23 June 2016].

Baloi, D. and Price, A. D. F., 2003. Modelling global risk factors affecting construction cost performance. *International Journal of Project Management*, 21(4), 261-269.

Crafford, G.J. and Smallwood, J.J., 2007. Clients' views on quantity surveying competencies. *Acta structilia: Journal for the physical and development sciences*, 14 (1), 33-55.

Dada, J. O. and Jagboro, G. O., 2012. Core Skills Requirement and Competencies Expected of Quantity Surveyors: Perspectives from Quantity Surveyors: Allied Professionals and Clients in Nigeria. *Australasian Journal of Construction Economics and Building*, 12(4), 78–90.

Energy Forum (Guarantee) Ltd., 2007. Incorporating Social and Environmental Concerns in Long Term Electricity Generation Expansion Planning in Sri Lanka: Final Report.

Fanous, A., 2012. *Surveying the Field: Changes in Quantity Surveying*. UK: Smashwords

Frei, M., Mbachu, J. and Phipps, R., 2013. Critical success factors, opportunities and threats of the cost management profession: the case of Australasian quantity surveying firms. *International Journal of Project Organisation and Management*, 5(1/2), 4-24.

Hore, A.V., O'Kelly, M. and Scully, R., 2009. *Seeley and Winfield's Building Quantities*. Irish Edition. Hampshire.

Ministry of Power and Renewable Energy, 2015. *Sri Lanka Energy Sector Development Plan for a Knowledge- based Economy 2015-2025*. Colombo: Ministry of Power and Energy.

Moss, J., 2004. The Future of Quantity Surveying. Available from: www.mosscost.com [Accessed 5th July 2016].

Olanrewaju, A. and Anahwe, P.J., 2015. Duties and responsibilities of quantity surveyors in the procurement of building services engineering. *Procedia Engineering*, *123*, 352-360.

Olatunde J., 2006. New Opportunities for Quantity Surveyors in Nigeria Business Environment, *21ST Century Quantity Surveying, Agenda for the Future*, Biennial. 1- 3 November.

Opawole, A., Awodele, O. A., Babatunde, S. O. and Awodele, O. O. P., 2012. Review of Correlation of Quantity Surveyors' Education in Nigeria to Skill Requirements for Administration of Civil Engineering Projects. *Journal of Education and Practice*, 3(16), 109–118.

Rameezdeen, R. and Jeyamathan, J., 2006. Skills and Competencies of Quantity Surveyors: The case of Sri Lanka. *Customizing the Quantity Surveyor to Face Challenges in Year 2020, 26 January 2006 Colombo.* University of Moratuwa: Department of Building Economics, 9-18.

Reddy, Y. B., 2015. The Changing Face of Quantity Surveying Practices in Construction Industry. Available from http://www.researchgate.net/publication [Accessed 9 June 2016].

Senaratne, S. and Sabesan, S., 2010. Managing knowledge as quantity surveyors: An exploratory case study in Sri Lanka. *Built-Environment Sri Lanka*, 8(2).

Sri Lanka Sustainable Energy Authority, 2007. *Sri Lanka Energy Balance 2007: An Analysis of Energy Sector Performance.* Colombo: Sri Lanka Sustainable Energy Authority

Thayaparan, M., Siriwardena, M., Amaratunga, D., Malalgoda, C. and Keraminiyage, K., 2011. Lifelong Learning and the Changing Role of Quantity Surveying Profession. *15th Pacific Association of Quantity Surveyors Congress*, Colombo. Pacific Association of Quantity Surveyors, 351-360.

Udo, M. A. and Abiola, A.H., 2015. An assessment of the Role of Quantity Surveying profession in the Development of Nigeria. *Knowledge Review*, 33(1), 1-6.

Willis, C., Ashworth, A. and Willis, J., 1994. *Practice and Procedure for the Quantity Surveyor*. 10th ed. Oxford: Blackwell Science.

Wirepa, S., 2001. The future of the Quantity Surveying. *Building Economics*, 12-15.

ARE GREEN BUILDINGS ECONOMICALLY SUSTAINABLE? A LCC APPROACH

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ABSTRACT

In the context of Sri Lanka, the number of green certified buildings is still at a minimal level and the reason could be attributed to green building investors who continue to perceive that green buildings are costly and the initial cost premium ranges from 20 to 25% and fail to appreciate the subsequent benefits in terms of running costs. However, in the global context, researchers have indicated that green building construction cost varies largely between -15 to 21% while only a little information is available on the status of operation and maintenance costs reduction. As part of the larger study which investigates the impact of sustainable features on life cycle cost of green buildings, this paper presents a comparison on life cycle cost of green certified industrial manufacturing building with that of a conventional building to establish the economic sustainability of green buildings. Quantitative data on the construction and running costs of green and conventional buildings were collected and analysed using Net Present Value. The analysis shows that the construction cost of green industrial manufacturing building is 28% higher than that of a conventional building while the reduction in running costs is 39%. Overall the green buildings offer an economic benefit of 50% savings over its life time. It is expected that the outcome of this research would contribute to the organisational learning of green built environment and thereby uplift the sustainable construction.

***Keywords**:Green Buildings; Green Rating Systems; Life Cycle Cost; Sri Lanka; Sustainable Features.*

1. INTRODUCTION

Green building creates environmentally responsible and resource-efficient structures and processes throughout its entire life-cycle beyond any classical building design concerns of economy, utility, durability and comfort (Environmental Protection Agency, 2017). Further, green buildings are said to be high performance building, focused to enhance the environment, social and economic sustainability pillars (Smith, *et al*, 2006). Green buildings reduce the environmental impacts significantly while using energy, water, and other resources efficiently by adopting various sustainable attributes such as sustainable sites, management, energy efficiency, water efficiency, materials and resources, indoor environmental quality, health and wellbeing etc.to resource conservation (USGBC, 2009). Given social, environmental and economic benefits, there exist some economic barriers which decide whether to execute a green building project or not. Amongst, perception of higher risk and investment costs (Hydes and Creech, 2000; Nelms, *et al*, 2005), lack of awareness among wider audience about major cost savings during operation (Ala-Juusela, *et al*, 2014), underestimating the potential cost savings, overestimating the capital costs of energy efficient measures and inadequate market value (Bartlett and Howard, 2000) are some of the significant barriers.

Morris and Langdon (2007) indicated that most of the buildings require a little or no additional cost to incorporate a reasonable level of sustainable design. However, Kats (2003), Stegall (2004), Nilson (2005) and Fowler and Rauch (2008) are of the view that the construction cost of a green building is higher than conventional building while there is a less operation cost. The authors further stated that usually higher premiums result in higher level of sustainability. Packard Foundation (2002) estimated that a premium of 0.9%, 1.3%, 1.5% and 2.1% of total hard costs which include excavation, foundation works, concrete flatwork, etc., is required to achieve LEED Certified, Silver, Gold, and Platinum for an office building, respectively. Another study conducted by Kats (2003) indicated that on average green cost premium is 0.66%, 2.11%, 1.82%, and 6.50% for Certified, Silver, Gold and Platinum respectively. A recently review of empirical evidence on green buildings cost premium shows that the green building cost premium is higher than that of conventional buildings and fall within a range from 0% to 21% Dwaikat and Ali (2016). A smaller percentage of the participants indicated that green buildings cost is less than their conventional counterparts and ranges from -4% to 0%. However, authors further concluded that there exists a significant gap in the quantified cost premiums and it is still questioned whether the green buildings cost more than its conventional counterparts. Yet, there is no conclusive answer to the question whether green buildings are economically sustainable?

According to researchers, the design cost of green buildings depend on several factors, including project location, building type, site conditions, local climate, and the familiarity with green design, modelling costs and time necessary to integrate sustainable building practices into projects and architectural and engineering design time (Kats, *et al*, 2008; Morris, 2007).Hence, the cost of green is highly subjective and previous studies demonstrated that cost-effective green designs are possible if sustainability goals, strategies and budgets are established and integrated in the pre-design stage (Morris, 2007; Kats *et al*., 2008). A visible limitation of the past studies is that the researchers were unable to quantify the running cost saving of the green buildings over its high construction cost. To that end, the current study compares the life cycle cost (LCC) of green and conventional buildings. LCC is a valuable tool to achieve cost efficiency in green building construction projects (Cole, 2000). The construction cost, the cost in use and the recovery cost should be considered at the outset of a construction project to identify the most economically viable project. In this end, there is a need to compare the LCC of green buildings with conventional buildings to address the issue of economic sustainability of green buildings.

In the Sri Lankan context, it was identified that the construction cost of green buildings is 20-25% higher than conventional buildings while the advantage gained is 10 times as much over the entire life of the building (Bombugala and Atputharajah, 2010). Further, Waidyasekara and Fernando (2012) stated that still fewer buildings have implemented the green concept in Sri Lanka due to lack of understanding among professionals about the period of achievement of economic savings of green buildings. Therefore, the extra investment cost needed for green buildings is found to be the primary barrier which restricts the implementation of green buildings in Sri Lanka. Green building investments are unattractive to those who expect fast investment returns. The foregoing review indicates that the cost commitment of green buildings is the prime concern and of contradictory views with respect to different contexts; type of building, climate condition, site conditions, etc. The contradictory nature of the previous studies in terms of construction cost premium of green buildings drove to current study. Further, the previous studies have no indication on running costs of green buildings compared to conventional buildings. The availability of quantitative evidence of running cost reduction in green buildings would enhance the investment on green buildings. The current study therefore compares the running cost of industrial manufacturing building and thereby establishes whether green buildings are economically sustainable?

2. FACTORS AFFECTING THE LCC OF GREEN BUILDINGS

Several studies have focused on comparison of green buildings with conventional buildings of similar type, size (Net Lettable Area), age, building tenancy and constructed in similar location (Packard Foundation, 2002; Kats, *et al*., 2003; Matthiessen and Morris, 2004; Langdon, 2007; Fullbrook and Woods, 2009).

Of them, Matthiessen and Morris (2004) highlighted that the cost of the green is influenced by demographic location: rural or urban, bidding climate and culture, local and regional design stages including codes and initiatives, intent and values of the project, climate, and timing of implementation, size of building and point synergies. Similarly, in an urban site the cost associated with storm water management, attempting to build green in an area where sustainable design is not a familiar concept, and contractors’ unwillingness to bid are some other factors which could significantly impact the cost of the green project. It is likely to impact the cost of building, if the building owner and the design team are unwilling to invest time and cooperation that may be needed to reach the desired certification level.

Further, Kim, *et al*. (2011); Mapp, *et al*. (2011); Shrestha and Pushpala (2012) explained that building size, type, function, location, climate and type of certification as the factors affecting to green buildings. These varying factors which affect the LCC of green buildings are classified as major and sub-factors and given in Table 1.

Table 1: Factors Affecting the LCC of Green Buildings

Main Factor	Sub Factor	Source
Managerial	Materials selection does not comply with client's activities Usage of cheaper/sub-standard materials Usage of new materials with little behaviour's information Lack of skilled labour, faulty workmanship and uneducated labours Poor management by maintenance personnel Lack of building maintenance manuals Poor communication between maintenance parties Failure to execute maintenance at the right time Interdepartmental boundaries Accelerated maintenance work due to poor budgetary control Unqualified maintenance contractors Unavailability of maintenance contractors	El-Haram and Horner (2002); Matthiessen and Morris (2004); Omari (2015)
Social	User does not understand importance of operation and maintenance work End users' behaviours Cultural practices High expectation of tenants Improper use of the property Vandalism by the tenant Delay in reporting failures	El-Haram and Horner (2002); Al-Khatam (2003); Omari (2015)
Environmental	Demographic location Physical site conditions Climate Environmental considerations	Kim, *et al*. (2011) and Mapp, *et al*. (2011); Shrestha and Pushpala (2012)
Financial	Inadequate finance Poor financial control on site and when executing maintenance work Market conditions Poor financial support for maintenance work	Lai, Yik and Jones (2010); Omari (2015)
Technical	Design complexity Faulty design Faulty maintenance Low concern to future maintenance Failure to identify the true cause of defects Selection of sub-optimal maintenance strategy Unfamiliarity with maintenance methods Type of structure Availability of services Resource availability Aging of building	El-Haram and Horner (2002); Al-Khatam (2003); Saghatforoush, Trigunarsyah, and Too (2012); Omari (2015)
Morphology	Plan shape Size of building Wall to floor ratio Degree of circulation space Storey height Total height of the building Grouping of buildings	Belniak and Zima (2013); Cunningham (2013); Ashworth and Perera (2015)
Other	Bidding climate and culture Local and regional design standards, including codes and initiatives Intent and values of the project Timing of implementation Point synergies Legislative constraints Method of construction Political factors Method of procurement	El-Haram and Horner (2002); Al-Khatam (2003); Matthiessen and Morris (2004); Omari (2015)

3. RESEARCH METHODOLOGY

The study involved two major phases: (1) a comprehensive literature review was carried out into previously published journal articles, books, trade publications and thesis to identify the green cost premium in the global context, (2) a comparative analysis was performed between the life cycle cost of a green building and conventional building. A green building and a conventional building with similar physical and performance characteristics were selected with due considerations to year of construction, Net Internal Area (NIA), and occupancy rate. The green case was identified conveniently, then carefully selected the conventional case with similar characteristics. Relevant real-life cost data: construction, annualised and periodic operation and maintenance, simulated end life cost and green building cost savings data were collected through document analysis according to the standard cost categories of Building Maintenance Cost Information Service (BMCIS). The green building construction budget, and operation and maintenance expenditure budget records were used to collect the cost data. Simultaneously, physical and performance data such as constructed year, number of floors, NIA, life cycle, building height and number of occupants were collected from the selected green and conventional buildings. The Net Present Value (NPV) analysis was used to measure the LCC of green buildings. All the costs were escalated at assumed inflation rate and then discounted for the base year. The analysis was carried out for 50 years at the discount rate of 4.26% obtained from the Central Bank of Sri Lanka. Finally, a sensitivity analysis is performed to determine the effects due to changes in discount rates and life cycle of the selected building.

4. ANALYSIS AND FINDINGS

4.1. COST OF GREEN BUILDINGS VS. CONVENTIONAL BUILDINGS

Previous studies which have compared the green buildings with similar natured conventional buildings have contributed to raise the awareness among investors and developers on the cost benefits and feasibility of implementing green buildings. The comprehensive review of empirical findings indicates that the cost premium of green building differs in terms of building type, certification level, cost estimation methods and sample size, etc. An in-depth analysis of LEED-NC certified buildings revealed that high performance sustainable building projects required higher capital investment and the required capital was proportional to the intended LEED-NC rating (Kats, 2003). According to Kats (2003), the cost premium of the green project is likely to be on increasing cost trend with respect to higher levels of green certification. On the other hand, Nilson (2005) estimated the LEED Gold certification to be 0.82% of total construction costs for an office building in New York. Also, Stegall (2004) estimated that a premium of 1-3% of the total project cost is required for a new house that aims to achieve LEED Silver certification.

In another situation, Kats (2006) conducted a study on 30 green school projects that were built in 10 different states during 2001 and 2006. According to results of the study, it was found that green school design involved 1-2% additional cost when compared with a conventional design. Author further explained that green buildings offer benefits that were 20 times as large over a 20-year period. Savings in health and productivity costs due to increased earnings, reduction in respiratory diseases, and higher employee retention made up 85% of total whole life cost savings, with savings in energy, water and waste contribute to remaining 15%. Another study that analysed 150 recently completed conventional and green buildings in 33 states across United States and 10 other countries concluded that green buildings cost up to 4% more than conventional buildings while most of the buildings cost only 1-2% more than conventional buildings. The study also found that energy used in green buildings reduced by 33% on average, and that energy cost savings alone over a 20-year study period outweighed the construction cost premium paid in these buildings (Kats *et al.*, 2008). In this sense, this section analyses the empirical findings of previous studies in terms of type of building, methodology adopted, sample size used, and certification level and the outcome. Table 2 presents the summary of findings of twenty-five (25) previous studies.

Table 2: Summary of Previous Studies on Green Cost Premium

Type of Building	Methodology Adopted	Outcome	Source
Office	Cost analysis of re-designing 03 existing buildings to green	-0.3 to 1.3%	Xenergy and Sera Architects (2000)
Office	Single case study: comparative cost analysis of modelled cost of green building against market baseline	LEED Certified: 0.9%; Silver: 13.1% Gold:15.5% Platinum 21%	Packard foundation (2002)
Office, School	Cost comparative analysis - actual cost of 33 green buildings against conventional design estimated through participants' perception	Average:1.84% LEED Certified: 0.66% Silver: 2.11% Gold: 1.82% Platinum: 6.5%	Kats, *et al.* (2003)
Office	Meta-analysis of secondary research and unspecified analysis of actual cost of green	Soft costs: -1.5 to 3.1% Hard costs: 3 to 8%	Northbridge Environmental Management Consultants (2003)
Office and Courthouse	Cost comparative analysis - modelled costs of 02 green buildings against conventional	-0.4% to 8.1%	Steven Winter Associates (2004)
Office	Single case study: cost comparative analysis	0.82%	Nilson (2005)
Office	Unpaired t-test of actual green fit-out costs of 12 green buildings against 13 non-green fit-out costs	No statistically significant cost difference	Davis Langdon (2007)
Office	Cost comparative analysis - modelled costs of 20 green building against conventional	4 Star 3 to 7% 5 Star 7 to15%	Fullbrook (2007)
Office	Single case study – Cost comparative analysis	4 Star: 1.25% 5 Star: 4.37% 6 Star: 6.23% Unrated: 2.91%	Fullbrook and Woods (2009)
Office	Cost comparative analysis - actual cost of 17 green buildings against modelled cost of conventional	No statistically significant cost difference	Rehm and Ade (2013)
Academic, laboratory and library	Unpaired t-test - actual cost of 45 LEED seeking buildings against 93 non-LEED seeking buildings	No statistically significant cost difference, Majority: No additional cost	Matthiessen and Morris (2004)
School	Cost comparative analysis - 30 green buildings against conventional	Average: 1.7%	Kats (2006)
Academic	Unpaired t-test - actual costs of 22 green building against non-green buildings	No statistically significant cost difference	Matthiessen and Morris (2007)
House	Single case study: itemized cost impact analysis	LEED Silver: 17%	NAHB Research Centre (2009)

School	Cost comparative analysis - 30 green buildings against 30 conventional	46%, Mean construction cost per square foot is significantly higher	Shrestha and Pushpala (2012)
Residential	Cost comparative analysis – 15 green projects against 22 conventional	Cost per square foot - no statistically significant cost difference	USGBC (2009)
Commercial	Cost comparative analysis - 12 green commercial interior projects and 13 conventional	Cost per square foot: no statistically significant cost difference	USGBC (2009)
Residential	Single case study: cost comparative analysis	10.77%	Kim, *et al.* (2014)
Healthcare	Cost comparative analysis - cost of 13 green and buildings against conventional	0 to 5%	Houghton, *et al.* (2009)
Bank	Cost comparative analysis - 02 green and conventional	No statistically significant cost difference	Mapp, *et al*. (2011)
Office Academic Healthcare School Library	Single case study – cost comparative analysis	1.5 to 6.5% -15% 1.50% 5.70% 4.90%	Fullbrook, *et al*. (2005)
Office	Participants' Perception	LEED Certified: 1.2% Silver: 2.25% Gold: 3.37% Platinum: 7.66)	Kats, *et al*. (2010)
Schools	Participants' Perception	LEED Certified: 0.35% Silver: 1% Gold: 1.3% Platinum: 9.6%	Kats, *et al*. (2010)
Academic building	Participants' Perception	LEED Certified: 1.65% Silver: 1.8% Gold: 1.93% Platinum: 2.53%	Kats, *et al*. (2010)
General	Participants' Perception	-5 to 10% Majority: 5 to 10%	Ahn and Pearce (2007)
General	Participants' Perception	1 to 15% Majority: 6 to 10%	Building Design and Construction (2007)
Healthcare	Participants' Perception	3 to 5%	
Higher education	Participants' Perception	3 to 5%	
School	Participants' Perception	11 to 15%	
Hotel	Participants' Perception	3 to 5%	
Restaurant	Participants' Perception	3 to 5%	
Residential	Participants' Perception	6 to 10%	
General	Participants' Perception	1 to 10% Majority: 5 to 10%	Park, Nagarajan and Lockwood (2008)
General	Participants' Perception	0 to 18% Majority: 0 to 4%	Kats (2010)

As seen from Table 2, studies have focused on various types of buildings such as residential - high-rise apartments, office, education, and hotel buildings, etc. Whilst rarely considered the industrial manufacturing category. Various cost estimation methods have been used to find out the cost premium of green buildings. Amongst, estimation of green cost through the survey respondents is the least applied method and Rehm and Ade (2013) pointed out that this method is less reliable and the findings are biased from the selected respondents. Comparing actual cost of green buildings with actual or modelled cost of conventional buildings and comparing modelled cost of green buildings with the modelled cost of conventional buildings are other methods which employed in the empirical investigations to estimate the cost premium of green buildings. Most of the empirical studies were conducted by trade organizations where the methods used to model the cost of the buildings are unclear.

Further, the cost premium for these buildings based different green certification levels in BREEM, Green Star and LEED rating systems. The cost premium increases with the certification level, the buildings with higher level of green often require increased green cost premium than lower certification level. Amongst the selected buildings for the previous studies, majority of the studies were conducted on office buildings and reported the highest green premium (21%).

Table 3 presents a further scrutiny of the findings shown in Table 2, according to the cost premium of different types of buildings.

Table 3: Summary of Cost Premium for Green Building

Type of Building	**Number of Studies (Cost Premium %)**						**Total (%)**
	Less than 0%	0%	0 - 5%	0 - 10%	0 - 20%	Higher than 20%	
Office	2	2	1	5	1	1	48%
Schools/ Higher Education	1	2	3	3	1	1	44%
Residential/House		1		1	2		16%
Healthcare			3				12%
Library		1	1				8%
Laboratories		1					4%
Hotel/Restaurant			1				4%
Bank		1					4%
Courthouse	1						4%
Other	1	1		1	2		20%
Total	20%	36%	36%	40%	24%	8%	

According to Table 3, most of the previous studies have focused on office and school buildings and the cost premium of those buildings ranges between less than 0% to above 20%. In case of residential buildings, the cost of green premium falls within 0-20%. Other categories of buildings such as healthcare, library, laboratories, and hotels/restaurants require only 5% increased cost of construction. However, Mapp, *et al*. (2011) indicated that the bank buildings require no additional cost for incorporating green features.

These variations in green cost premiums among different types of buildings and inadequacy in methods adopted to assess the green cost premium have driven the current study to compare the life cycle cost of a conventional industrial building with a similar type of green building and confirm whether green buildings are economically sustainable. The green space for industrial manufacturing buildings has received the top most position with 18 out of 38 LEED certified green buildings in Sri Lanka to date.

The next section presents the life cycle cost analysis of two buildings: Green vs. Conventional.

4.2. PROFILE OF CASES

Having considered the factors influencing the sustainability, a conventional building constructed in similar location and climatic condition, with similar tenure, i.e. management style and quality, equal age and size of the selected green building was chosen. In addition, physical and performance characteristics such as year of construction, number of floors, shape, NIA, designed life cycle, building height and number of occupants were matched between the two buildings. Table 4 presents the profile of the selected two buildings.

Table 4: Profile of the Buildings

Building	**Year**	**Number of floors**	**Shape**	**NIA (m2)**	**Life Cycle**	**Building height(m)**	**Number of Occupants**	**Function**
Green	2013	1	Rectangular	3567	50	4.0	1310	Garment
Conventional	2013	2	Rectangular	4032	50	7.8	1340	Garment

As observed from Table 4, the year of construction, shape of the building and designed life cycle are similar for both buildings while the green building is smaller in terms of number of floors, building height, and NIA. However, these minor differences are not expected to affect the life cycle cost substantially.

4.3. LCC COMPARISON BETWEEN GREEN AND CONVENTIONAL BUILDINGS

As discussed in the methodology, the NPV of the two buildings were calculated for the analysis period of 50 years using a discount rate of 4.26%. Relevant cost data required for the NPV calculations were collected according to the standard cost categories suggested by Building Maintenance Cost Information Service (BMCIS). Table 5 illustrates the summary of comparison. All the costs were discounted back to year 2013 and normalised considering cost per m^2 of NIA.

Table 5: LCC between Green and Conventional Buildings

LCC	Green Building (GB) cost per m^2 (LKR)	Conventional Building (CB) cost per m^2 (LKR)	Green Building Cost Impact $\frac{\text{PV of GB} - \text{PV of CB}}{\text{PV of GB}} * 100\%$
Construction Cost	81,081.68	58,699.34	28%
Running Cost	401,218.27	557,873.96	-39%
NPV	482,299.95	616,573.31	-28%
Validation			
Total Cost Saving of Green Building (Energy cost-40%, Water cost-50%, Waste Recycling-95%, Reduced absenteeism-2%)			50%
Ddt: Cost of implementing and maintaining sustainable features of Green Buildings (Approx.)			22%
Net Effects due to sustainable features			28%

According to Table 5, the construction cost of the green building is 28% higher than that of the conventional building. However, running cost is comparably less than that of conventional building by 39% due to the 50% of benefits accrued through life cycle of green building. According to the data collected from the selected green building, the green building saves 40% of energy cost, 50% of water cost, 95% of waste recycling and 2% of cost due to reduced absenteeism. From this 50% of saving 22% cost is trade off due to the cost of implementation and maintaining of sustainable features incorporated to the green building. Therefore, this deduction ultimately gives 28% of net saving. This similar saving is obtained through LCC comparison between green and conventional buildings. Therefore, it is safe to conclude that the LCC of green building is 28% less than that of a conventional building.

4.4. SENSITIVITY ANALYSIS OF LCC

It is often required to carry out a sensitivity analysis in life cycle cost analysis in order to ensure the consistency of the findings with respect to changes in assumptions made. The two key assumptions used for this study are discount rate of 4.26% and the life cycle of 50 years. Therefore, a sensitivity analysis was performed to examine how variations across range of uncertainties could affect the NPV values being compared. Table 6 shows the sensitivity analysis of green building LCC impact, at various discount rates (3.41%, 4.22%, 4.26%, 4.69 and 5.11%) and the effect of changing the life cycle of the buildings (40, 45, 50, 55 and 60 years respectively).

Table 6: Sensitivity Analysis with Changing Discount Rates and Life Cycle

Sensitivity Analysis	Parameter Change %	-20%	-10%	0%	10%	20%
Sensitivity Analysis Stage 1	Discount Rate	3.41%	4.22%	4.26%	4.69%	5.11%
	Life time of the building	50	50	50	50	50
	Green building LCC Impact	-30%	-30%	-28%	-27%	-28%
Sensitivity Analysis Stage 2	Discount Rate	4.26%	4.26%	4.26%	4.26%	4.26%
	Life time of the building	40	45	50	55	60
	Green building LCC Impact	-27%	-28%	-28%	-28%	-28%

The sensitivity analysis indicates that when the discount rates and life cycle vary ±10% or ±20%, the green building LCC impact varies 0-2% and varies 0-1% respectively. However, these changes in LCC are insignificant. This analysis further confirms the finding that the life cost of green building is 28% less than a similar type of conventional building.

5. CONCLUSIONS

In the Sri Lankan context, the industrial manufacturing buildings are at the forefront in terms of green certification. A total of 18 (out of 38) LEED certified green industrial buildings are in operation. However, are these buildings economically sustainable? It is not evident in the global or local context that how much a green industrial space costs and benefits over its life cycle. Previous studies suggest that the upfront cost concern is one of the main barriers which exist when deciding whether to execute a green building project (Hydes and Creech, 2000; Nelms, *et al*. 2005). Whereas some researchers argue that reasonable levels of sustainable design can be incorporated into most building types at little or no additional cost (Dwaikat and Ali, 2016).

On that note, a single case study approach was adopted where the life cycle cost of a green building and a similar natured conventional industrial building were compared. According to comparison, the life cycle cost of green building is 28% less than that of a conventional building while the green building offers a saving of 39% in terms of running cost. However, the initially cost attributed to green features are 28% higher than a similar type of conventional industrial building. This finding is of the similar view of Bombugala and Atputharajah (2010) who concluded that the construction cost of green buildings is 20-25% higher than traditional buildings in Sri Lanka. However, majority of the previous studies done in other countries reported that the green cost premium is between 0 to 10% while few studies explaining that the green building construction cost premium could be increased up to 20 or more than 20%. As a departing point of findings, this current study reports the status of green industrial buildings. According to findings green industrial buildings are economically sustainable with the overall saving of 28% achievable over its life time. It is expected that this study would enhance the green investors to take informed decision upfront and thereby contribute to achieve higher level of sustainability at large.

6. REFERENCES

Ahn, Y. and Pearce, A., 2007. Green construction: contractor experiences, expectations, and perceptions. *Journal of Green Building***,** 2(3), 1–17.

Ala-Juusela, M., Short, M. and Shvadron, U., 2014. Tools to support sustainable entrepreneurship in energy positive neighbourhoods. *Entrepreneurship and Sustainability Issues***,** 2(2), 49-59.

Al-Khatam, J. A., 2003. *Buildings Maintenance Cost***.** King Fahd University of Petroleum and Minerals, Dhahran.

Bartlett, E. and Howard, N., 2000. Informing the decision makers on the cost and value of green building. *Building Research and Information***,** 28(5-6), 315-324.

Bombugala, B. A. and Atputharajah, A., 2010. Sustainable development through Green Building Concept in Sri Lanka. In: *International Conference on Sustainable Built Environment (ICSBE-2010)***,** Kandy, 13-14 December 2010. 19-24.

Building Design and Construction, 2007. Green buildings research white paper [Online]. Available from: http://www.bdcnetwork.com/bdcs-2007-green-buildings-researchwhite-paper-where-building-owners-end-users-and-aecprofessionals/ [Accessed 29 May. 2017].

Building Maintenance Cost Information Service, 1984. *Standard form of property occupancy cost analysis: principles, instructions, definitions and elements.* London: Connelly-Manton (Printing).

Cole, R. J., 2000. Editorial: Cost and Value in Building Green. *Building Research and Information,* 28(5-6), 304-309.

Davis Langdon, 2007. *Cost of Green Revisited: Re-examining the Feasibility and Cost Impact of Sustainable Design in the Light of Increased Market Adoption.* Davis Langdon.

Dwaikat, L. N. and Ali, K. N., 2016. Green buildings cost premium: A review of empirical evidence. *Energy and Buildings,* 110, 396–403.

Environmental Protection Agency, 2017.Basic Information: Green Building [online]. Available from: https://archive.epa.gov/greenbuilding/web/html/about.html [Accessed 12 Jun. 2017].

Fowler, K. M. and Rauch, E. M., 2006. *Sustainable Building Rating Systems Summary.* Battelle: U.S. Department of Energy.

Fullbrook, D., 2007. *Value cases for achieving Green Star NZ 4 Star and 5 Star environmental ratings in commercial office buildings.* Wellington: Ministry for the Environment.

Fullbrook, D. and Woods, J., 2009. *Value case for Green Star-rated fitting out of central government office accommodation (ME 934),* Wellington: Ministry for the Environment.

Fullbrook, D., Jackson, Q. and Finlay, G., 2005. *Value case for sustainable building in New Zealand (ME 705).* Wellington: Ministry for the Environment.

Heerwagen, J. H., 2000. Green Buildings, Organizational Success, and Occupant Productivity. *Building Research and Information,* 28(5), 353-367.

Hydes, K. and Creech, L., 2000. Reducing mechanical equipment cost: the economics of green design. *Building Research and Information,* 28(5/6), 403–407.

Houghton, A., Vittori, G. and Guenther, R., 2009. Demystifying first-cost green building premiums in healthcare. *Journal of Health Environment Research and Design,* 2, 10-45.

Kats, G., 2003. *Green Building Costs and Financial Benefits.* Westborough, MA: USA for Massachusetts Technology Collaborative.

Kats, G., 2006. *Greening America's schools: Costs and benefits, A Capital E report*, Westborough, MA: U.S. Green Building Council.

Kats, G., 2010.*Greening Our Built World: Costs, Benefits, and Strategies.* Washington, DC: Island Press.

Kats, G., Alevantis, L., Berman, A., Mills, E. and Perlman, J., 2003. *The costs and financial benefits of green buildings: A report to California's Sustainable Building Task Force.* Available from: http://www.usgbc.org/Docs/News/News477.pdf [Accessed 28 March. 2017]

Kats, G., Braman, J. and James, M. 2010. *Greening our built environment: Costs, benefits, and strategies.* Washington, DC: Island Press.

Kats, G, James, M, Apfelbaum, S, Darden, T, Farr, D and Fox, R., 2008. Greening buildings and communities: costs and benefits. A Capital E report, Westborough, MA: U.S. Green Building Council.

Kim, J., Greene, M. and Kim, S., 2014. Cost comparative analysis of a new green building code for residential project development. *Journal of Construction Engineering and Management,* 140, 1–10.

Lai, J., Yik, F. and Jones, P., 2008. Expenditure on operation and maintenance service and rental income of commercial buildings. *Facilities*, 26(5/6), 242 - 265.

Mapp, C., Nobe, M. and Dunbar, B., 2011. The cost of LEED—an analysis of the construction of LEED and non-LEED banks. *Journal of Sustainability and Real Estate,* 3(2011), 254–273.

Matthiessen, L. and Morris, P., 2004. Costing green: A comprehensive cost database and budgeting methodology [Online]. Available from: http://www.davislangdon.com/USA/Research/ResearchFinder/2004-Costing-Green-A-Comprehensive-Cost-Database-and-Budgeting-Methodology [Accessed 4 May. 2017].

Matthiessen, L. and Morris, P., 2007. Cost of green revisited. [Online]. Available from: http://www.davislangdon.com/USA/Research/ResearchFinder/2007-The-Cost-ofGreen-Revisited/.[Accessed 29 May. 2017]

Morris, P., 2007. What does green really cost? *PREA*, Quarterly (2007), 55–60.

Morris, P. and Davis Langdon, 2007. What Does Green Really Cost? The Green Issue Feature, *PREA*, Quarterly (summer), 55-60.

NAHB Research Centre, 2009. *The added cost of greening a new home* [Online]. Available from: http://www.toolbase.org/PDF/CaseStudies/LCCTC_AddedCostGreeninNewHome.pdf_ [Accessed 29 May. 2017].

Nelms, C., Russel, A. D. and Lence, B. J., 2005. Assessing the performance of sustainable technologies for building projects**.** *Canadian Journal for Civil Engineering*, ***3***2, 114-128.

Nilson, M. L., 2005. *Quantifying the cost impacts of LEED-NC Gold construction in New York City***.** Thesis (Senior Honours). Lafayette College.

Northbridge Environmental Management Consultants. 2003. *Analyzing the cost of obtaining LEED certification*. [Online]. Available from: http://www.cleanair--coolplanet.org/for_communities/ LEED_links/AnalyzingtheCostofLEED.pdf/.[Accessed 29 May. 2017].

Omari, D. O., 2015. *An Investigation into Factors Affecting the Maintenance Cost of Commercial Buildings in Nairobi***,** Kenya: School of the Built Environment.

Packard Foundation, 2002. *Building for sustainability report***,** Los Altos, CA: The David and Lucile Packard Foundation.

Park, C., Nagarajan, S. and Lockwood, C., 2008. The dollars and sense of green retrofits. [Online]. Available from: http://www.deloitte.com/assets/DcomUnitedStates/Local%20Assets/Documents/us_re_Dollars_Sense_Retrofits_190608_pdf/ [Accessed 29 May. 2017].

Rehm, M. and Ade, R., 2013.Construction costs comparison between “green” and Conventional office buildings. *Building Research and Information***,** 41(2013), 198–208.

Saghatforoush, E., Trigunarsyah, B., and Too, E. G., 2012. Assessment of Operability and Maintainability Success Factors in Provision of Extended Constructability Principles. In: *9th International Congress on Civil Engineering***,** Isfahan-Iran, May. 2012. Isfahan University of Technology, 8-10.

Shrestha P.P. and Pushpala, N., 2012. Green empirical and non-green school buildings: a comparison of construction cost and schedule. *Construction Research Congress***,** 1820–1829, (2012, ASCE 2012).

Smith, T. M., Fischlein, M., Suh, S. and Huelman, P., 2006. *Green building rating systems: A comparison of the LEED and green globes systems in the US*. St. Paul: University of Minnesota.

Steven Winter Associates, 2004. *GSA LEED cost study*. [Online]. Available from: http://www.wbdg.org/ccb/GSAMAN/gsaleed.pdf/. [Accessed 29 May 2017].

Stegall, N., 2004. *Cost implications of LEED Silver certification for new house residence hall at Carnegie Mellon University***.** Thesis (Senior Honours), Carnegie Mellon University.

United States Green Building Council, 2009. Green Building Facts. [Online]. Available from: http://www.usgbc.org/ [Accessed 15 April 2017].

Waidyasekara, K. G.A. S. and Fernando, W. N., 2012. Benefits of Adopting Green Concept for Construction of Buildings in Sri Lanka. In: *2nd International Conference on Sustainable Built Environment 2012 (ICSBE)***,** December 2012, Kandy, Sri Lanka. 1-13.

Xenergy and Sera Architects, 2000. *Green city buildings: Applying the LEED rating system, a report prepared for Portland Energy Office*, Portland, Oregon [Online]. Available from: http://neea.org/docs/reports/casestudyongreencitybuildingsmarketresearchreport.pdf [Accessed 29 May. 2017].

ASSESSING SUSTAINABILITY OF ROAD PROJECTS IN SRI LANKA

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ABSTRACT

Road construction is a continuously evolving notion and a key player in nation's economy. It has been identified as causing a range of countless environmental, social and economic impacts. Hence, there is a dire necessity of Sustainability Assessment (SA) in road construction. Many developed countries have their own rating systems for assessing road construction although this is lacking in developing countries. However, a commonly accepted assessment method for road construction over its life cycle is not available up to date. Addressing these gaps, this paper presents a framework for SA in road projects in Sri Lanka pertaining to construction activities associated in road life cycle under the three pillars of sustainability; i.e. Environmental, Social and Economic. A comprehensive literature survey was executed exploring road sustainability impacts and measures globally. An expert survey was carried out under two rounds with three professionals in road construction and sustainability to verify literature findings, and to explore more sustainability impacts and measures in road construction in Sri Lanka. A framework was developed including 10 major road sustainability impacts, 13 sub-impacts and 29 measures in a hierarchical structure. A pairwise comparison was carried out for the elements in the framework distributing 32 questionnaires among professionals. Collected data were analysed using Analytic Hierarchy Process (AHP). Analysed results weighted each element with a score resulting "Standard of living (0.2362)" and "Resource usage (0.2228)" as the most significant impacts where "Measures of improving Accessibility (0.1205)" as the most significant measures in the framework.

***Keywords**: Life Cycle; Road Construction; Sustainability Assessment; Sustainable Development.*

1. INTRODUCTION

Sustainability as an evolving notion is presently pointed out as a global issue that requires a concentrated global solution (Ugwu *et al.,* 2006). It is almost always addressed under three dimensions: environmental, social and economic which is usually referred as triple bottom line of sustainability (Goel, 2010, Simpson *et al*., 2014). Road construction as an evolving sector and a key player in nation's economy has been identified as causing a range of countless environmental and socio-economic impacts.

Horvath and Hendrickson (1998) found one-kilometer (km) length of typical two lane road with flexible pavement consumes seven terajoule (TJ) of energy where Chu *et al*., (2007) found aggregate base can require 25,000 tonnes (t) aggregate material per km. Lepert and Brillet (2009) emphasized road projects utilize considerable land use with high resource consumption due to its geometry, pavement structure, surface condition and high energy input due to traffic congestion. Therefore, sustainability should be addressed along with road construction practices. Thereby SA methods are focused as a mean to analyze aforementioned impacts (Zhang *et al.,* 2013).

SA can be noted as any process that directs decision making towards sustainability (Gibson, 2006). Pears (2005) stated it is useful to look any industry at a life cycle perspective in SA. Rooshdi *et al.* (2014) revealed sustainable rating systems have become popular as green assessment methods in many nations. However, SAs are lacking in developing countries.

In Sri Lanka, there is no any such rating system developed for road construction so far. Environmental Impact Assessment (EIA) process is the general practice of SA of road construction in Sri Lanka which was introduced through the National Environmental Act (Central Environmental Authority, 2013). However, road SA is

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indispensable in any kind of economy especially in developing economies where construction is still in an evolution virtually (United Nations, 2013). Considering the above facts, this paper attempts to develop a SA framework to assess road construction practices in Sri Lanka.

Most of the rating systems focus on buildings and therefore development of a method for SA in infrastructure is a vital necessity. United Nations (2013) stated the contexts of developed and developing countries are different to each other. Therefore, the assessment methods launched in developed countries are not ideal to apply in developing countries. Moreover, a type specific environmental rating system in infrastructure is lacking worldwide (Jayawickrama *et al.*, 2013). In addition to that Gamalath *et al.* (2014) emphasized EIA which is used in infrastructure SA in Sri Lanka is not effective to assess a project accurately due to insufficient post monitoring plan and lack of incorporation of sustainable concepts. Thus, aiming inapplicability of road SAs found in developed countries into developing countries and the absence of type specific rating systems for infrastructure in developing countries, this research aimed to develop a framework for assessing sustainability in road projects in Sri Lanka .

2. METHODOLOGY

This research focuses on “new road constructions” within Sri Lankan context and it addresses only the construction activities associated with road projects over its life cycle. The SA framework addresses both the environmental, social and economic lines of sustainability. The objectives of this study justify the use of mixed research approach as the most suitable research approach to the study. Since road construction is not similar as other industries, the respondents for the data collection were selected based on purposive sampling method. Thus, the experts and professionals who have experience and knowledge on road construction and sustainability were employed in this study.

The study begun with an expert survey with three professionals under two rounds. It was conducted to filter road sustainability impacts and measures found in literature to the Sri Lankan context while exploring more impacts and measures. The survey aimed to develop the hierarchy for the framework by grouping filtered road sustainability measures under applicable road sustainability impacts.

The questionnaire survey of this study was arranged to conduct over four different questionnaires: questionnaires A, B, C and D. Data collected through questionnaire were analyzed using AHP technique. Questionnaire A consists of pairwise comparisons on road sustainability impacts/ sub-impacts where questionnaires B, C and D consist of pairwise comparisons on sustainability measures under environmental, social and economic aspects respectively. Since AHP technique was employed in many studies with a small sample group; five respondents (Al-Harbi, 2001; Peterson *et al*., 1994), seven respondents (Armacost *et al*., 1994) and the like, 8 number of questionnaires were collected in this study under each questionnaire type. Though the employed sample size in this study is smaller, it is adequate to represent the population because the sample size is not critical in AHP analysis if the representativeness of the sample is secured to speak for the population.

3. LITERATURE REVIEW

3.1. SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT

Sustainability is the challenge of current century which does economic development in a way that reduces environmental impacts while improving social needs (Newman, 2015). Sustainability can be outlined under three aspects namely economic, environmental and social which are usually referred to as triple bottom line of sustainability (Goel, 2010; Robins, 2006). Among them most of the times environmental dimensions are considered as most prioritized components in Sustainable Development (SD) before taking economic and social dimensions in to consideration (Egilmez and Tatari, 2012). But the aforementioned three dimensions are interrelated and therefore when looks for SD both should be simultaneously evaluated (Rosa, 2011; Satolo and Simon, 2015).

3.2. SUSTAINABLE DEVELOPMENT IN ROAD CONSTRUCTION

Roads can be identified as one of the largest and complex mega projects in the construction industry which influenced to millions of general public at the project end (Flyvbjerg, 2014). Roads have various impacts towards environment, social and economic sustainability (Thrope, 2012). Those issues which associate in road projects emphasized the necessity of addressing sustainability in road construction. Sarsam (2015) outlined three attributes a road might embedded as a “sustainable road”. Those are; lower level of impact to the environment, more positive outcomes to the society and lower level of life cycle cost.

3.3. ROAD LIFE CYCLE AND CONSTRUCTION ACTIVITIES

Life cycle of a road is analyzed by Stripple (2001) under three main stages. Those three phases are construction phase, operational and maintenance phase and final disposal phase. The first phase, construction phase includes removal of buildings, topsoil, vegetation around the construction area and removal of unsuitable soils such as soft soils (Birgisdóttir, 2005). Further to the author it includes construction of the road structure: sub grade, sub-base, base course and wearing course. In addition to that it associated with activities like construction of drainage systems and adding different road equipment, signs, safety fences, road lighting and so on (Birgisdóttir, 2005). The next phase, operational and maintenance stage includes maintenance of pavement, clearing road verges and maintenance of road equipment like activities which are necessary to keep a road in an acceptable condition during its service time (Stripple, 2001; Birgisdóttir, 2005). When considered about the final phase of the life cycle, mostly there is no end life to an old road because when the road is at its end phase, the practice is replacing or reconstructing the old road with a new roadway instead of removing (Stripple, 2001).

Many studies highlighted variety of sustainability impacts which can account under road construction as discussed in Table 1. Therefore, as Sarsam (2015) and Pears (2005) depicted assessing road sustainability characteristics and implementing them during its life cycle is significant.

3.4. ROAD SUSTAINABILITY ASSESSMENT

SA method presents whether the expected progress has been made while bringing out decisions on present and future situations on SD (Brandon and Lombardi, 2011; Hacking and Guthrie, 2008). Poveda and Young (2015) revealed two questions which must be answered prior to assess sustainability. First what is to be measured and second how to measure. Thereby this study was organized to measure sustainability in road construction exploring road sustainability impacts and measures (measures refer the steps which can take in road construction to achieve sustainability).

3.5. ROAD SUSTAINABILITY IMPACTS

Exploring various sources available in global context such as Civil Engineering Environmental Quality Assessment and Award Scheme (CEEQUAL), New York State Department of Transportation (NYSDOT), Illinois Department of Transportation (IDOT) and Illinois Joint Sustainability Group (IJST) and the like, Table 1 below consolidates environmental, social and economic sustainability impacts connected with construction activities. By means of construction, those impacts can be taken into consideration when developing the SA framework for road construction. The impacts addressed in the first column of Table 1 are described henceforth.

Impacts due to land use - According to Jayawickrama *et al.* (2013), future availability of productive land is determined the way that land is utilized. The impact to the land can be considered in two forms as land use in terms of area and land composition (Jayawickrama *et al.*, 2013)

Impacts due to resource usage - In the Envision rating system the impacts cause due to material usage, water utilization and energy usage are embedded under the main category named resource allocation (ISI, 2016).

Impacts due to land use - According to Jayawickrama *et al.* (2013), future availability of productive land is determined the way that land is utilized. The impact to the land can be considered in two forms as land use in terms of area and quality (Jayawickrama *et al.*, 2013)

Table 1: Sustainability Impacts Accountable in Road Construction

Sustainability impacts		Sustainability			Sources										
		Environmental sustainability	**Social Sustainability**	**Economic Sustainability**	Gudmundsson (2004)	Litman and Burwell (2006)	CEEQUAL (2010)	NYSDOT (2010)	Muench *et al.* (2011)	IDOT and IJST (2012)	Jayawickrama *et al.* (2013)	Rooshdi *et al.* (2014)	Bueno *et al.* (2014)	Almahmoud and Doloi (2015)	ISI (2016)
Land use	Land use in terms of area	√	×	×	√	×	√	√	√	√	√	√	√	×	√
	Land use in terms of quality	√	×	×	√	×	√	√	√	√	√	√	√	×	√
Resource usage	Material usage	√	×	×	√	√	√	√	√	√	√	√	√	×	√
	Energy usage	√	×	×	×	√	√	√	√	√	√	√	√	×	√
	Water efficiency	√	×	×	×	√	√	√	√	√	√	√	×	×	√
Waste	Solid waste	√	×	×	√	×	√	√	√	√	√	√	×	×	√
	Liquid waste	√	×	×	√	×	√	√	√	×	√	√	×	×	√
	Gaseous waste	√	×	×	√	√	√	√	√	√	√	√	√	×	√
Noise and vibration		√	√	×	√	×	√	√	√	×	×	√	×	×	√
Biodiversity		√	×	×	√	√	√	√	√	√	√	√	√	×	√
Standard of Living	Capital performance	×	√	√	×	×	×	×	×	×	×	×	×	√	√
	Phycological comfort	×	√	×	×	√	×	×	×	×	×	×	√	√	√
	Integration with community	×	√	×	×	√	√	×	×	×	×	×	√	√	√
Community mobility and access		×	√	×	√	√	×	×	√	√	×	×	√	√	√
Health and safety		×	√	×	√	√	√	√	×	×	×	×	√	√	√
Culture		×	√	×	×	×	√	×	√	×	×	×	×	√	√
Direct cost	Initial cost of construction	×	×	√	√	×	×	×	√	×	×	×	√	×	×
	Operational and maintenance cost	×	×	√	√	×	×	×	√	×	×	×	√	×	×

Impacts due to resource usage - In studies, the impacts due to resource consumption are discussed in three forms; impacts due to material, water and energy. In the Envision rating system the impacts cause due to material usage, water utilization and energy usage are embedded under the main category named resource allocation (ISI, 2016).

Impacts due to waste - The waste release in road construction is discussed in CEEQUAL manual in three forms as solid waste, liquid waste and gaseous waste (CEEQUAL, 2010).

Noise and vibration - construction can cause considerable nuisance to the natural and social environment (CEEQUAL, 2010).

Impacts to the biodiversity- Constructions are being identified as one of the root causes which damage and destroy the wildlife habitat and the species diversity (CEEQUAL, 2010).

Impacts to the standard of living - Impacts to the standard of living is addressed under three sub-impacts; capital performance, psychological comfort and integration with community. The study of Almahmoud and Doloi (2015) on "social sustainability in construction" addresses capital performance as satisfying the needs of community through providing job opportunities, generating investment opportunities and the like. Psychological comfort refers comfort of the mind, promote equity and satisfying territorial needs of the community. Integration with community refers to engaging community with the project.

Impacts to the community mobility and access - The accessibility performance of the project along its lifecycle is addressed under this heading (Almahmoud and Doloi, 2015). According to the authors a social sustainable project should not interrupt to accessibility and those should allow secure and safe open paths.

Impacts to the health and safety - The construction projects should adhere with health and safety requirements (Almahmoud and Doloi, 2015). According to Bueno *et al*. (2014) the impact to the health and safety due to road construction can be classified under social as well as economic sustainability impacts.

Impacts to the culture - According to the Greenroads Manual culture refers to community values, cultural awareness and art (Muench *et al.*, 2011).

Direct cost - The direct cost is considered under two sub impacts. Firstly, the initial cost of the construction address cost associated in the initial phases, material extraction to end of construction phase where the operational and maintenance cost refers to construction costs associated with road operational and maintenance phases (Bueno *et al*., 2014).

3.6. ROAD SUSTAINABILITY MEASURES

Sustainability measures provide significant involvement towards establishing greener construction practices. According to Montgomery *et al.* (2014), project specific measures to be implemented to mitigate negative environmental and socio-economic impacts of a project. Exploring the available literature, Figure 1 summarises road sustainability measures acknowledged in road related sustainable rating systems and various studies worldwide with the intention of achieving road sustainability.

1. Reduce landscape degradation
2. Avoid impacts to high quality undeveloped lands
3. Reduce excavated material taken off site
4. Avoid impacts to sites with threatened or endangered species
5. Minimize spreading of invasive species
6. Protect wildlife and its habitat
7. Planting trees, shrubs and/or native plants
8. Use locally produced or regional materials
9. Use recycled materials
10. Reduce energy consumption
11. Use renewable energy
12. Reduce water consumption
13. Monitor water quality parameters
14. Control run off water (Having catchments, drainage systems)
15. Reduce equipment emission
16. Incorporate sustainable lighting
17. Reduce community disruptions
18. Provide views of scenery/ visual enhancement
19. Incorporate required sound /noise level during working time
20. Minimize dust
21. Provide buffer between road and high quality wet land
22. Balance the earthwork
23. Protect the culture
24. Having road side maintenance plans
25. Accommodate safe pedestrian access
26. Provide income generation methods to the community

Figure 1: Road Sustainability Measures

Sources: (CEEQUAL, 2010, 2016; IDOT and IJST, 2012; ISI, 2010; Muench *et al*., 2011; NYSDOT, 2010; Rooshdi *et al.,* 2014)

4. RESEARCH FINDINGS

4.1. EXPERT SURVEY FINDINGS

The expert survey findings revealed both the sustainability impacts/sub-impacts and measures discovered under literature survey (refer Table 1 and Figure 1) can be considered in Sri Lankan context when assessing sustainability in road construction. Additionally, the survey identified measures namely, "Avoid liquid waste from equipment and machinery", "Having standard measures to increase public and worker health and safety" and "Dispose waste to suitable locations". Thus, the expert survey concludes 10 major road sustainability impacts with several sub-impacts and 29 road sustainability measures for the road SA framework. Moreover, the expert survey findings disclosed the relationship among road sustainability measures with each sustainability impact, sub-impact. That structured the hierarchy for the framework and it is shown in Figure 2.

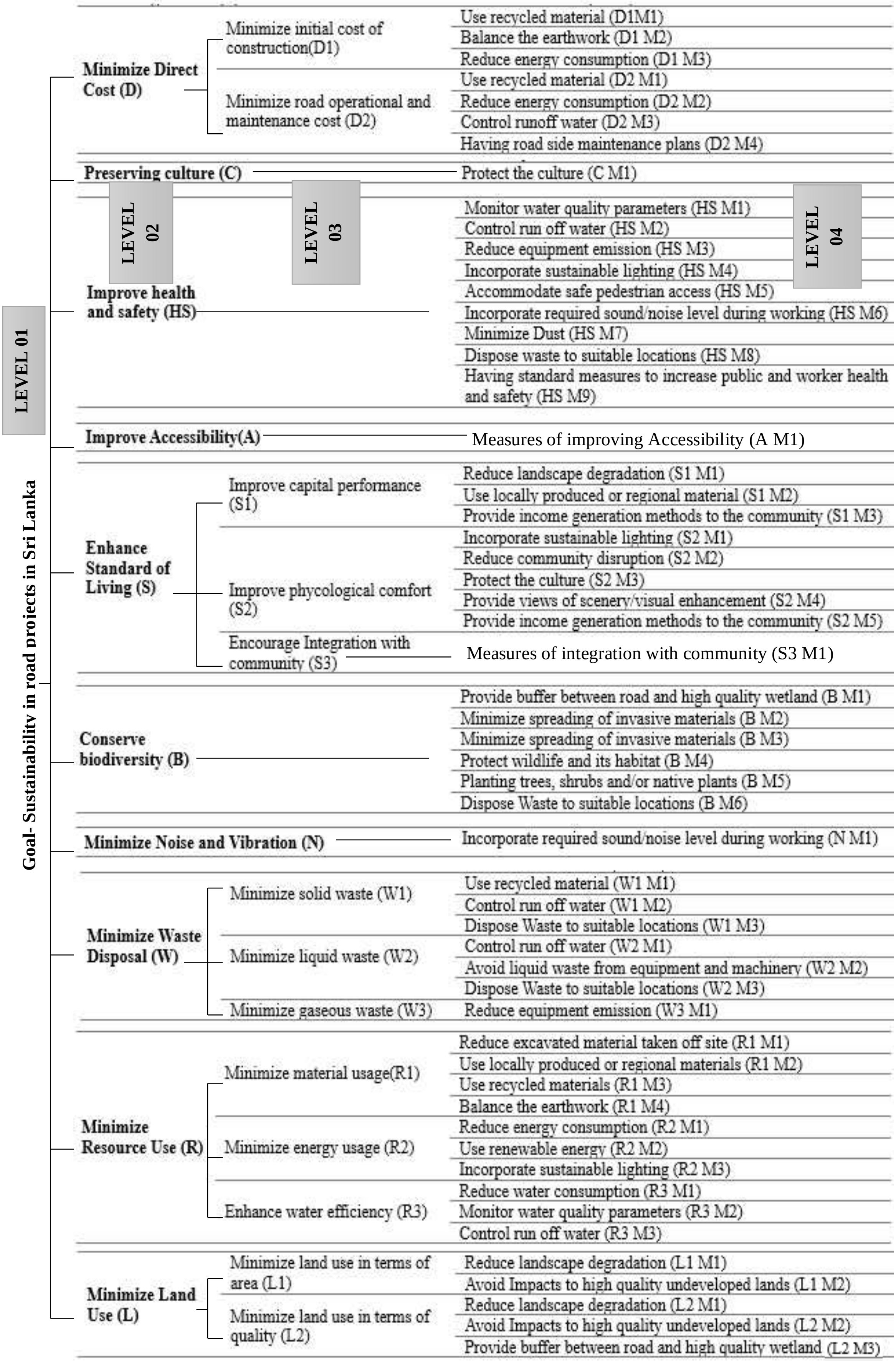

Figure 2: Structure of the Road SA Framework

The hierarchical structure ensured four levels to the framework, goal at the top level or the first level, main road sustainability impacts at the second level, sub impacts of road sustainability at the third level and road sustainability measures at the bottom level or the fourth level.

4.2. *QUESTIONNAIRE SURVEY FINDINGS*

The questionnaire survey findings were analyzed using AHP technique. The results of relative weightages for each road sustainability impact, sub impact and measure (elements of the hierarchy) were calculated using the geometric mean of individual's results. The weighted scores for each main impact, sub impact and measures under AHP analysis are depicted in following Table 2.

Table 2: Weighted Scored under AHP Analysis

Main impacts	Priority vector	Final weight (X1)	Rank	Sub-impacts	Priority vector (X2)	Final weight (X1X2) = X4	Rank	Measures	Priority vector (X3)	Final weight (X4X3)	Rank
L	0.0304	0.0304	9	**L1**	0.4130	0.0125	2	**L1 M1**	0.5838	0.0073	1
								L1 M2	0.4162	0.0052	2
				L2	0.5870	0.0178	1	**L2 M1**	0.1521	0.0027	3
								L2 M2	0.3886	0.0069	2
								L2 M3	0.4593	0.0082	1
R	0.2228	0.2228	2	**R1**	0.4871	0.1086	1	**R1 M1**	0.1667	0.0181	3
								R1 M2	0.1782	0.0193	2
								R1 M3	0.1639	0.0178	4
								R1 M4	0.4912	0.0533	1
				R2	0.2060	0.0459	3	**R2 M1**	0.3610	0.0166	2
								R2 M2	0.2237	0.0103	3
								R2 M3	0.4153	0.0191	1
				R3	0.3069	0.0684	2	**R3 M1**	0.4741	0.0324	1
								R3 M2	0.2983	0.0204	2
								R3 M3	0.2276	0.0156	3
W	0.0673	0.0673	6	**W1**	0.6183	0.0416	1	**W1 M1**	0.4332	0.0180	2
								W1 M2	0.1127	0.0047	3
								W1 M3	0.4541	0.0189	1
				W2	0.2655	0.0179	2	**W2 M1**	0.1102	0.0020	3
								W2 M2	0.7389	0.0132	1
								W2 M3	0.1508	0.0027	2
				W3	0.1162	0.0078	3	**W3 M1**	0.0076	0.0076	1
N	0.0326	0.0326	8					**N M1**	0.0326	0.0326	1
B	0.1096	0.1096	4					**B M1**	0.1198	0.0131	5
								B M2	0.3461	0.0379	1
								B M3	0.1018	0.0112	6
								B M4	0.1731	0.0190	2
								B M5	0.1356	0.0149	3
								B M6	0.1236	0.0135	4
S	0.2362	0.2362	1	**S1**	0.4805	0.1135	1	**S1 M1**	0.2392	0.0272	3
								S1 M2	0.3418	0.0388	2
								S1 M3	0.4190	0.0476	1
				S2	0.1731	0.0409	3	**S2 M1**	0.0632	0.0026	5
								S2 M2	0.4150	0.0170	1
								S2 M3	0.1180	0.0048	4
								S2 M4	0.1206	0.0049	3
								S2 M5	0.2833	0.0116	2
				S3	0.3464	0.0818	2	**S3 M1**	0.0818	0.0818	1
A	0.1205	0.1205	3					**A M1**	0.1205	0.1205	1
HS	0.1072	0.1072	5					**HS M1**	0.0597	0.0064	8
								HS M2	0.0548	0.0059	9
								HS M3	0.1647	0.0177	1
								HS M4	0.0698	0.0075	7
								HS M5	0.1617	0.0173	2
								HS M6	0.1520	0.0163	4
								HS M7	0.1590	0.0170	3
								HS M8	0.1041	0.0112	5

Main impacts	Priority vector	Final weight (X1)	Rank	Sub-impacts	Priority vector (X2)	Final weight (X1X2) = X4	Rank	Measures	Priority vector (X3)	Final weight (X4X3)	Rank
								HS M9	0.0742	0.0080	6
C	0.0296	0.0296	10					**C M1**	0.0296	0.0296	1
D	0.0436	0.0436	7	**D1**	0.3137	0.0137	2	**D1M1**	0.1830	0.0025	3
								D1 M2	0.4913	0.0067	1
								D1 M3	0.3257	0.0045	2
				D2	0.6863	0.0299	1	**D2 M1**	0.1120	0.0034	4
								D2 M2	0.3068	0.0092	1
								D2 M3	0.2881	0.0086	3
								D2 M4	0.2930	0.0088	2

Based on the above findings the aim of this research, developing the SA framework for road construction practices in Sri Lanka was accomplished. According to the AHP results, the 10 major road sustainability impacts can be arranged pertaining to the scores as S, R, A, B, HS, W, D, N, L, and C respectively. According to the AHP weightages, “S” is as important as “R” making both almost equally important in achieving road sustainability. When it comes to combined weightages of each road sustainability measure “Measures of improving Accessibility (0.1205)” act as the most significant measure in terms of road SD.

5. DISCUSSION

Based on the findings on literature (refer Table 1) and the scores of each impact/sub-impact (Main impact and sub-impact score columns in Table 2), the percentages of the combined weightages of each pillar of sustainability are 40.38%, 45.91% and 13.71% for environmental sustainability, social sustainability and economic sustainability respectively. In fact, social and environmental sustainability aspects are seen to be almost equally significant than economic sustainability in terms of road construction. Further it distinguishes that social and environmental impacts are nearly three times significant than economic sustainability impacts. Thus, it can be noted that road constructions are immensely associated with impacts to the social and natural environments. The Green guide for roads rating system which was originated in year 2008 has allocated the highest points, standing at 45% (Simpson *et al.*, 2014) for the social sustainability. It can be noted that the arrangement of this proposed road SA framework is same as the arrangement of the Green guide for roads rating in terms of triple bottom line of sustainability concept. However, the scores embedded in major road sustainability impacts are differ in the proposed framework from the available road rating systems though the percentage of the combined scores given to the particular impact seems almost similar. That score difference of the major road sustainability impacts between the research findings and the current road related rating systems must have occurred as a result of; this research being based on a developing country’s context and almost all the other existing road related rating systems are being based on developed countries’ context.

6. CONCLUSIONS

This study attempted to develop a SA framework for road construction practices in Sri Lanka. Further, it provides an insight to the various researches on road sustainability. The literature noted that sustainability of any industry to be assessed over its life cycle. Further, the literature revealed when looking for SD the three dimensions of sustainability: environmental, social and economic should be simultaneously evaluated. Thus, this framework addressed sustainability in road construction at a life cycle perspective under triple bottom line of sustainability concept. The relative weights of elements in the framework demonstrate the level of significant of each impacts/sub-impact and measure towards SD along road construction practices. The results were proven road constructions are highly associated with impacts to social and environmental lines than economic line. Therefore, a noticeable attention should be given to natural and social environment when looking for SD over road construction practices.

7. REFERENCES

Al-Harbi, K.M.A.S., 2001. Application of the AHP in Project Management. *International Journal of Project Management*, 19, 19-27.

Almahmoud, E. and Doloi, H.K., 2015. Assessment of social sustainability in construction projects using social network analysis. *Facilities, 33*(3/4*),* 152-176.

Armacost, R.L., Componation, P.J., Mullens, M.A. and Swart,W.W., 1994. An AHP framework for prioritizing customer requirements in QFD: an industrialized housing application. *IIE Transaction*, 26, 72–79.

Birgisdóttir, H., 2005. *Life cycle assessment model for road construction and use of residues from waste incineration*. Lyngby: Institute of Environment & Resources, Technical University of Denmark.

Brandon, P.S. and Lombardi, P.L., 2011. *Evaluating sustainable development in the built environment*. 2nd ed. Hoboken: Wiley-Blackwell.

Bueno, P.C., Vassallo, J.M. and Cheung, K., 2014. *Road infrastructure design for optimizing sustainability* [online]. Available from: http://www.ptcarretera.com/wp-content/uploads/2015/08/Cuaderno-Tecnol%C3%B3gico-2014_TRANSyT.pdf [Accessed 6 August 2016].

Central Environmental Authority. 2013. *Environmental Impact Assessment (EIA) procedure in Sri Lanka* [online]. Available from: http://www.cea.lk/web/index.php/en/environmental-impact-assessment-eia-procedure-in-sri-lanka [Accessed 2 July 2016]

Chu, S., Goldemberg, J., Arungu-Olende, S., El-Ashry, M., Davis, G. and Nakicenovic, N., 2007. *Lighting the way: Toward a sustainable energy future*. Amsterdam: Inter Academy Council.

Civil Engineering Environmental Quality Assessment and Award Scheme. 2016. *Improving sustainability through best practices* [online]. Available from: http://www.ceequal.com [Accessed 21 July 2016].

Egilmez, G. and Tatari, O., 2012. A dynamic modeling approach to highway sustainability: Strategies to reduce overall impact. *Transportation Research Part A: Policy and Practice*, *46*(7), 1086-1096.

Flyvbjerg, B., 2014. What You Should Know About Megaprojects and Why: An Overview. *Project Management Journal*, *45*(2), 6-19.

Gamalath, I.M., Perera, H.L.K. and Bandara. J.M.S.J., 2014. Environmental impact assessment of transport infrastructure projects in Sri Lanka: Way forward. *Tropical Forestry and Environment*, 4(1), 85-96.

Gibson, R.B., 2006. Sustainability assessment: basic components of a practical approach. *Impact Assessment and Project Appraisal*, 24(3), 170-182.

Goel, P. (2010). Triple bottom line reporting: An analytical approach for corporate sustainability. *Journal of Finance, Accounting & Management*, *1*(1), 27-42.

Gudmundsson, H., 2004. Sustainable transport and performance indicators. *Issues in Environmental Science and Technology*, 35-64.

Hacking, T. and Guthrie, P., 2008. A framework for clarifying the meaning of triple bottom-line, integrated, and sustainability assessment. *Environmental Impact Assessment Review*, *28*(2-3), 73-89.

Horvath, A. and Hendrickson, C., 1998. Comparison of environmental implications of asphalt and steel-reinforced concrete pavements. *Transportation Research Record: Journal of the Transportation Research Board*, 1626.

Illinois Department of Transportation and Illinois Joint Sustainability Group. 2012. *Illinois – Livable and Sustainable Transportation Rating System and guide* [online]. Available from: http://www.eastsidehighway.com/wp-content/uploads/2014/05/I-LAST-Version-2-DRAFT.pdf [Accessed 2 July 2016].

Institute of Sustainable Infrastructure. 2016. *Sustainability Strategy | Institute for Sustainable Infrastructure* [online]. Available from: http://sustainableinfrastructure.org/envision [Accessed 23 July 2016].

Jayawickrama, T.S., Ofori, G. and Pheng, L.S., 2013. A framework for environmental rating schemes for infrastructure projects. In: *proceedings of the second World Construction Symposium 2013: Socio-Economic Sustainability in construction*, Sri-Lanka 14-15 June 2013. Sri-Lanka: Ceylon Institute of Builders.

Lepert, P. and Brillet, F., 2009. The overall effects of road works on global warming gas emissions. *Transportation Research Part D: Transport and Environment*, 14(8), 576-584.

Litman, T. and Burwell, D., 2006. Issues in sustainable transportation. *International Journal of Global Environmental Issues*, *6*(4), 331.

Montgomery, R., Schirmer, J.H. and Hirsch, A., 2014. A sustainability rating system for roads in developing countries. In *International Conference on Sustainable Infrastructure 2014*. Long Beach 6-8 November 2014.

Muench, S.T., Anderson, J.L., Hatfield, J.P., Koester, J.R. and Söderlund, M., 2011. Greenroads manual v1.5. In: J.L. Anderson, C.D. Weiland and S.T. Muench, ed. Seattle: University of Washington.

New York State Department of Transportation. 2016. *GreenLITES* [online]. Available from: https://www.dot.ny.gov/programs/greenlites [Accessed 18 July 2016]

Newman, P.W., 2015. Transport infrastructure and sustainability: A new planning and assessment framework, *Smart and Sustainable Built Environment*, 4(2), 140-153.

Pears, A., 2005. Sustainability and roads: Capturing the ESD Opportunity. *Urban Policy and Research*, 23(2), 235-245.

Peterson, D.L., Silsbee, D.G. and Schmoldt, D.L., 1994. A case study of resources management planning with multiple objectives and projects. *Environmental Management*, *18*(5), 729-742.

Poveda, C.A. and Young, R., 2015. Potential benefits of developing and implementing environmental and sustainability rating systems: Making the case for the need of diversification. *International Journal of Sustainable Built Environment*, *4*(1), 1-11.

Robins, F., 2006. The challenge of TBL: A responsibility to whom? *Business and Society Review*, 111(1), 1-14.

Rooshdi, R.R., Rahman, N.A., Baki, N.Z., Majid, M.Z. and Ismail, F., 2014. An evaluation of sustainable design and construction criteria for green highway. *Procedia Environmental Sciences, 20,* 180-186.

Rosa, D.J., 2011. Sustainability and infrastructure resource allocation. *Journal of Business & Economics Research (JBER)*, *7*(9).

Sarsam, S.I., 2015. Sustainable and green roadway rating system. *International Journal of Scientific Research in Environmental Sciences*, *3*(3), 99-106.

Satolo, E.G. and Simon, A. T. (2015). Critical analysis of assessment methodologies for intraorganizational sustainability. *Management of Environmental Quality*, *26*(2), 214-232.

Simpson, S.P., Ozbek, M.E., Clavenger, C.M. and Atadeso, R.A., 2014. *A Framework for assessing transportation sustainability rating systems for implementation in U.S. state departments of transportation* [online]. Available from: http://www.mountain-plains.org/pubs/pdf/MPC14-268.pdf [Accessed 25 August 2016].

Stripple, H, ed., 2001. *Life cycle assessment of road: A pilot study for inventory Analysis* [online]. Available from: http://www3.ivl.se/ rapporter/pdf/B1210E.pdf [Accessed 5 June 2016].

Thrope, D., 2012. Evaluating factors in sustainable road construction and management: A life cycle approach. *Proceedings of the 28th Annual Conference on Association of Researchers in Construction Management* [online]. United Kingdom 3-5 September 2012. Available from http://www.arcom.ac.uk/-docs/proceedings/ar2012-1235-1244_Thorpe.pdf [Accessed 10 July 2016].

Ugwu, O., Kumaraswamy, M., Wong, A. and Ng, S., 2006. Sustainability appraisal in infrastructure projects (SUSAIP): Part 2: A case study in bridge design. *Automation in Construction,* 15(2), 229-238.

United Nations., 2013. *World economic and social survey 2013: Sustainable development challenges*. New York: Author.

Zhang, J., Xie, H., Liu, M. and Liu, K., 2013. Study on traffic and infrastructure construction performance assessment based on sustainable development. In: Chen, F., Liu, Y., Hua, G. ed. *International Conference on Low-carbon Transportation and Logistics and Green Buildings.* Beijing 2013. 23-29.

BIM FOR FACILITIES INFORMATION MANAGEMENT

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ABSTRACT

Successful adoption of Building Information Management (BIM) during design and construction phases is recurrent, and the benefits achieved through such adaptation had been encouraged to extend BIM in to other phases of construction including facilities management. However, a limited application of BIM in construction facilities management is noted. This paper reveals the potential use of BIM in FM phase, by giving more priority on 'value of information'.

The paper is based on a detailed literature review. The first section reveals the application of BIM in AEC/FM environments and second section discusses the industry standards and guidelines behind BIM in FM. The findings of the literature review explain that the key technological features attached to BIM drive for its wide application, however most of these features are tailored to design and construction tasks rather helping in FM tasks. A non-realisation of value of information is identified as a key issue for limited adoption of BIM in FIM. Therefore, the paper recommends to identify the value of BIM in its complete sense (information, technology and pocess) to understand the FM information requirement and technical developments that is necessary for specific FM needs.

Keywords: *Building Information Modelling (BIM); BIM Standards; Facilities Management (FM); Information Value.*

1. INTRODUCTION

Construction industry has stepped forward into digital construction through Building Information Modelling (BIM). BIM is a digitised approach supporting through life application of building information with an information exchange and interoperability capacity (Eastman, 2011). A frequent adoption of BIM during design and construction phases is identified (Eadie *et al*., 2013), and if this extends towards the facilities management (in-use) phase, significant benefits can be further expected. Information rich BIM models are capable of overcoming the issues of handover process (Kassem, Kelly, Dawood, Serginson and Lockley, 2015). Although the application of BIM is dominant in early stages of a building, owners and facilities manager have good potentials in achieving benefits of through life BIM adoption (Eadie *et al*., 2013; Howard and Björk, 2008). However, it is important to note that all the potential benefits are based on the information it carries and information passed through to the facilities managers and owners may depend on the clear specification of employer information requirement (EIR) at the early stages.

Having identified the lack of motivation in facilities management sector in adopting BIM for FM tasks, this paper reveals the key reasons for such slow pace adoption. The first section of the paper discusses the key features of BIM and it's through life applications in construction context. When considering the through-life application of BIM in construction, an extra effort needs to be made in early stages of a facility to identify the EIR, although very little payback/incentives were given for such efforts. Therefore, this paper further investigates the available approaches for identifying the EIR at the early stage of project initiation. The standards and guidelines which support the decision on specifying information requirements and their limitations are also discussed where appropriate. Finally, paper argues that there is a clear gap in current knowledge on realising value of BIM beyond a mere digital model.

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2. BUILDING INFORMATION MODELLING IN AEC/ FM ENVIRONMENTS

Building information modelling was initiated in Architecture, Engineering and Construction (AEC) sectors of construction industry because of its visualisation ability (Volk, Stengel and Schultmann, 2014). This was further extended to FM industry. Visualisation has made a major impact on adopting BIM in AEC/FM environments. A shift from 2D platform to a BIM environment is a significant value addition in current design and construction environments. Moving forward, this is also recognised as a significant feature to be considered in facilities management functions. Visualisation through 3D modelling has been popular in daily operations and management as well as to understand root causes for the problems in FM (Patacas, *et al.*, 2015). One such example is scenario planning for refurbishment projects with least disturbance to existing structure (Kassem *et al.*, 2015), and locating building components (Korpela *et al.*, 2015). Scenario planning is one of the commonly achieved benefits by adopting BIM in FM.

Collaboration is another key feature in BIM. It solves many issues encountered due to the fragmented nature of the construction industry (Eadie *et al.*, 2013). In other words, BIM brings all stakeholders together into a single platform taking them out from the silo environments. This feature has the highest positive financial contribution to BIM projects during design and construction stages (Eadie *et al.*, 2013). Yet, there is hardly any evidence on considering collaboration in FM tasks. Cost modelling is another such use of BIM which is benefited at the early stages of a construction projects (Eadie *et al.*, 2015) yet no straightforward application beyond the construction phase.

Clash detection is a similar impressive feature, which facilitates the review of different drawings (architectural, mechanical, structural etc.) together to detect any physical clashes. This feature is a value addition of BIM and it is well recognised for the savings made by detecting potential variations/rework before starting the actual construction work (Eadie *et al.*, 2013). However, there is no considerable contribution to the FM tasks with this feature other than the potential small scale refurbishments which could take place during in-use phase.

Straight forward benefits of BIM for FM has been identified as significant time savings at the transfer of as-built information to the CAFM systems, and efficient handover process (Korpela *et al.*, 2015). Delivering handover information through digital format minimises the unnecessary time and rework in data transferring at the facilities management stage (Akcamete *et al.*, 2010). Although digital information is not a unique feature of BIM, it is considered as a value addition which comes along with it. This digitised aspect also add value in design and construction stage with altering design drawings over and over again with little effort. Another important feature is the intelligence. BIM model identify the space and objects for what they are rather symbolising (Ding *et al.*, 2014). Application of this feature could be seen in different occasions throughout the life cycle.

FM is trying hard to make some use out of the given BIM features. Figure 1 considers BIM features with FM expectations.

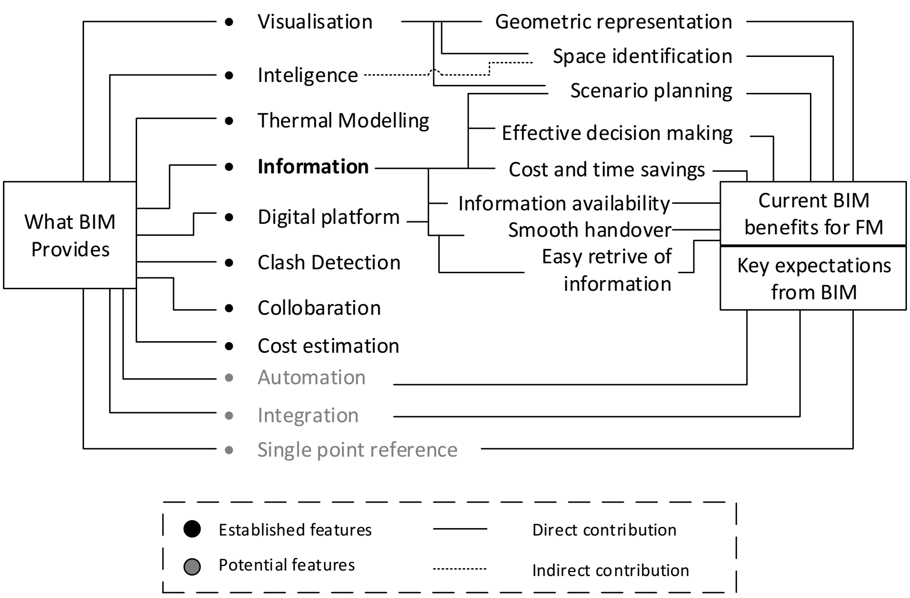

Figure 1: Mapping BIM Features with FM Expectations

For instance, visualisation through 3D modelling is a key feature in BIM, and it is utilised in FM for scenario modelling, presentation and management purposes. Therefore, visualisation is a feature which promotes the investment in BIM in FM. Another well recognised feature is clash detection. It has proven to be beneficial in design and construction stages more often. However, this is not an attractive proposition to promote BIM in FM. Likewise many established features are dedicated to improve the efficiency and effectiveness in design and construction stages rather in FM. On the other hand, most of the FM related BIM features are merely seen on papers to exaggerate the potential contribution of BIM for FM.

It is information which makes all above features possible (Antón and Díaz, 2014; Arayici, Onyenobi and Egbu, 2012), and it is the key value addition to FM through BIM. Therefore, it is essential that necessary information are included in the BIM model without information overloading (Parsanezhad and Dimyadi, 2014). Referring to the above features, it is clear that most of the exciting features are mainly for design and construction purposes and not many have an impressive contribution for facilities management. However, beyond the unique features, information carried through BIM has a greater potentials in FM (Eadie *et al.*, 2013). Therefore, it is critical to understand the facilities management information requirements to make the best use of BIM. A lack of experience and knowledge related to information requirements is a key reason for the limited adoption of BIM in FM (Giel and Issa, 2016). Therefore, the successful adoption of BIM in FM will depend on the understanding of value of information for facilities management and integrating these information in to BIM models. Identifying value of information is knowing what you need (Zhao *et al.*, 2008) indeed it is a filtering mechanism to separate what we need from what we want. The next section considers the standards and guidelines which supports identifying facilities management information requirements.

3. FACILITIES MANAGEMENT RELATED BIM STANDARDS AND GUIDELINES

Facilities Management (FM) is the integration of processes within an organisation to maintain and develop the agreed services which support and improve the effectiveness of its primary activities (European Standard EN 15221.1, 2007). The FM process focuses on managing the complexities of a built facility to smooth functioning of its physical structure and support services to enhance the core business performance (Kincaid, 1994). Towards achieving such targets, the information flows during FM stage is significant.

FM deals with enormous amount of asset information; including acquiring, updating and analysing of them (Wang *et al.*, 2013). BIM as a platform evolving from the early stages of a building is a perfect solution for FM data management. BIM allows to communicate FM needs at early stages of projects (British Institute of Facilities Management, 2012). The positive contributions of BIM for facilities information management (FIM) is identified as a significant value addition to FM (Gu and London, 2010). Eadie *et al.* (2013) explain facilities managers and clients benefit the most out of BIM implementation. Klein *et al.* (2012) argue that a considerable effort should be given to define client's FM needs at the project briefing stage. However, majority of BIM enabled projects are reluctant to handover the complete 3D model and Construction Operations Building Information Exchange (COBie) datasets at the commissioning stage of such built assets, which prevents BIM adoption in FM (Eadie *et al.*, 2013).

Standards and guidelines are the most common way to understand the information needs at the early stages of a building. Having identified the potentials of BIM and its long-term benefits, the number of standards developed under this theme is rising fast. Table 1 summarises the standards and guidelines related to construction information management through BIM. The summery of the available standards reveals that major concerns related to BIM implementation is addressed. However, they do not provide a complete solution in specific to FM information requirements (Patacas *et al.*, 2015).

Table 1: FM Information Related BIM Standards

Standard/ Guideline	Relevant facts for information management
BS 8587:2012 Guide to Facility Information Management (British Standards Institute, 2012)	• Information management strategy, policy and procedure • FM handbook containing legal, commercial, financial, technical and managerial information about the facility • Recommends COBie • Asset registry

Standard/ Guideline	Relevant facts for information management
ISO/WD 19650 - 1 (PAS 1192 - 2) Organisation of information on construction works - Information management using building information modelling - Part 1: Concepts and principles	• Relevant standards for BIM and information management • Relationship between documents used for information management • Information delivery cycle and responsible parties for each stage • Content areas of EIR • Information classification – Uniclass • Information Exchange - COBie
ISO 19650 - 2 (PAS 1192 - 3) Organisation of information on construction works - Information management using building information modelling - Part 2: Delivery phase of assets	• Relevant asset information standards • Information management plan • Asset information process • Content of the Asset Information Model (AIM) • Link between AIM and enterprise system • Need of a data manager to enhance accuracy of data
BS 1192 - 4:2014 Collaborative production of information Part 4: Fulfilling employers information exchange requirements using COBie - Code of practice	• Assist information demand side • The role of employer, design/contractor lead and subcontractors/manufactures in information exchange • Purposes of required facility information
CIC BIM Protocol Standard Protocol for use in projects using Building Information Models (Construction Industry Council, 2013)	• Need of an information manager • A form to be attached with the contract documents explaining BIM model needs specifically with data drops at different project stages, types of software and version to be used
Uniclass 2015 A universal classification system for the construction industry	• A classification system for building elements and products
ISO 16739:2013 Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries (British Standards Institute, 2013)	• A standard format for data exchange • Provide categories and coding system for building elements and assets
BS 8536-1:2015 Briefing for design and construction. Code of practice for facilities management (Buildings infrastructure)	• Early involvement of the FM for information requirement identification • Transfer of information from Project Information Model to Asset Information Model • Specified after care period to extend the service of the project team after the handover of the facility
Digital Plan of Work	• Web-based free tool to guide the information responsibilities and delivery at each stage of the construction project • Defines information requirements

4. VALUE OF INFORMATION

Understanding value of information forms the foundation to recognise value of BIM. The term 'value' is multifaceted, providing different meanings to different stakeholders. Therefore, what is communicated by term value could make a significant difference in the choice of adopting BIM. At a glance, it is the 'cost' over 'benefits', which represents the ultimate worth of the considered matter (Neal and Strauss, 2008). Literature suggest several mechanisms to determine the value of information. From a case study analysis, Gavirneni *et al.* (1999) developed an equation to measure the value in supply chain information flow. The equation is integrated with the monetary, performance and lead time improvements made through availability of information. Similarly, by elaborating factors considered as benefits in value equation, Neal and Strauss (2008) introduced a measurement tool to capture the brand value. Both methods have been considered as successful attempts due to the structured nature of the manufacturing industry/products. There are key facts which can be taken forward to determine the value of information in facilities management yet not solely applicable due to heterogeneous characteristics in construction projects.

When being specific on information, allocation of a monetary value to a piece of information is not always practical (Gallagher, 1974).The method which is popular in manufacturing industry compares two situations of performing a task with and without completed information (Gavirneni *et al*., 1999). However, value is something more “adjectival rather substantive”, therefore, it should be considered along with object and interest (Perry, 1914). Moreover, Gallagher (1974) suggested three possible ways to measure the value of information. Among those three methods, measuring the value after the information is being used and the consequences of the action are known as the best method to determine the value of information. Having considered such characteristics of value of information, this paper adopts “practical consequences result by construction information towards achieving the FM functions” as the value of information. Thus, the value-in-use is considered as its concerns fit with the characteristics of FM information, which assists to understand the uses of information within FM. Repo (1986) explained value-in-use as the benefits of information to its users which includes both subjective and objective in nature.

5. DISCUSSION AND CONCLUSIONS

Building Information Modelling (BIM) in construction considers use, reuse and exchange the relevant information throughout the building life cycle (Korpela *et al.*, 2015) while ensuring the efficiencies in terms of time, cost, and quality. To promote this good practice, responsible authorities around the world either recommend or have made it mandatory to use BIM in current construction projects (Kassem *et al.*, 2015). This influence is a clear reason to why it has slowed down the adoption of BIM in FM as it is a regulations pushed strategy practiced in related to BIM in FM rather a market pull strategy. The forecasted theoretical benefits of adoption of BIM in FM and popularity of BIM in design and construction phases have overrun the practical concerns of FM with regards to BIM. As a result, most of the information passed through BIM models during handover are useful for architects and contractors rather to facilities managers and owners (Clayton *et al.*, 1999; East, Nisbet and Liebich, 2013). As this make no good to facilities management, use of BIM model limits to fulfilling mandatory requirement of having a BIM model and no contribution to the efficiency in performing FM tasks. Therefore, there is a critical need to reflect on the facilities management needs in BIM concept in order to take BIM beyond construction.

Also, BIM process requires considerable effort in identifying and defining EIR in order to have a whole life application. In contrary, BIM does not provide an attractive payback for facilities management compared to the effort it demands in considered time frame. In a nutshell, current potentials of BIM does not bring a significant contribution compared to the current CAFM systems, hence facilities managers and owners are not much motivated to adopt BIM beyond construction (Korpela *et al.*, 2015). Particularly, FM related technical features such as automation and integration with rest of the CAFM systems are key expectations of FM. However, with the current trends in technological developments, this could be expected to be solved in near future.

The most common known reasons for backwardness in FM to adopt BIM is lack of tangible benefits, standard specifications, BIM skills, knowledge and resistance to change (Kassem *et al.*, 2015). Although there are number of standards and guidelines covering almost every area of BIM in FM to help adopting BIM, their usability depend on certain assumptions. For instance, PAS 1192 series gives a detail guidance on the process of defining information requirements to acquire asset information for FM. However, this is under the assumption that facilities manager is involved at the briefing stage of the project and/or client is well-informed about his requirements. Yet, both these assumptions are not frequent in current FM practices.

In conclusion, it can be noted that BIM is continuously moving forward from design construction phases to facilities management phase. However, such adaptation appears to be driven by the regulations and mandatory requirements rather than on a realisation of potential value that can be obtained by the client. On the other hand, the broader concept of BIM offers benefits in facilities management phase. Especially in wider sense with big data, internet and virtual reality. The narrow focus towards BIM as a technology (3D model) and/or an information management platform has limited its application. Therefore, there is a gap in identifying the value of BIM as a complete package. Secondly, construction industry has a low record in moving forward with technology and improving efficiency. Introducing concepts and standards works for an ideal market would not fit for an industry which is not motivated through innovation and competitive market trends. Therefore, when considering the value, it is necessary to accept the backwardness in the industry with moving forward with high-tech solutions for the mere reason that *it is the trend*. The value is the trigger point to BIM for FM since the gap is not in what BIM is but how it is being packaged. Having understood the importance of value of information for facilities management is an achievement in itself, with or without BIM, under given circumstances as it is increasing the need to understand the value of information to make decision in an information driven world. As BIM provides through life economic benefits to project stakeholders, there should be a mechanism to promote BIM within FM information management. The paper recommends 'value of information' as a core mechanism that needs to be considered throughout the lifecycle of the project.

6. REFERENCES

Akcamete, A., Akinci, B. and Garrett, J.H., 2010, June. Potential utilization of building information models for planning maintenance activities. In: *International conference on computing in civil and building engineering*, 151-157. June.Florida, USA

Antón, L.Á. and Díaz, J. 2014. Integration of Life Cycle Assessment in a BIM Environment. *Procedia Engineering,* 85(1), 26-32.

Arayici, Y., Onyenobi, T. and Egbu, C. 2012. Building information modelling (BIM) for facilities management (FM): The MediaCity case study approach. *International Journal of 3D Information Modelling,* 1(1), 55-73.

British Institute of Facilities Management. 2012. *BIM and FM: Bridging the gap of success.* Herts: British Institute of Facilities Management.UK

British Standards Institute. 2012. *BS 8587:2012 Guide to facility information management.* [Online] Available from: http://search.ebscohost.com/login.aspx?direct=trueanddb=edsbsiandAN=edsbsi.30259859andsite=eds-live. [Accessed: 15 June 2016]

British Standards Institute. 2013. *Industry foundation classes (IFC) for data sharing in the construction and facility management industries.* [Online] Available from: http://search.ebscohost.com/login.aspx?direct=trueanddb=cat01284aandAN=ljmu.001074347andsite=eds-live. [Accessed: 15 June 2016]

Clayton, M.J., Johnson, R.E. and Song, Y. 1999. Operations documents: addressing the information needs of facility managers. *Durability of building materials and components,* 8(4), 2441-2451.

Construction Industry Council 2013. *Building Information Model (BIM) Protocol.* CIC/BIM Pro. CIC:London

Ding, L., Zhou, Y. and Akinci, B. 2014. Building Information Modeling (BIM) application framework: The process of expanding from 3D to computable nD. *Automation in Construction*, 46, 82-93.

Eadie, R., Browne, M., Odeyinka, H., Mc keown, C. and Mc niff, S. 2015. A survey of current status of and perceived changes required for BIM adoption in the UK. *Built Environment Project and Asset Management*, 5(1), 4-21.

Eadie, R., Browne, M., Odeyinka, H., McKeown, C. and McNiff, S. 2013. BIM implementation throughout the UK construction project lifecycle: An analysis. *Automation in Construction,* 36, 145-151.

East, E.W., Nisbet, N. and Liebich, T. 2013. Facility Management Handover Model View. *Journal of Computing in Civil Engineering*, 27(1), 61-67.

Eastman, C.M. 2011. *BIM handbook : a guide to building information modeling for owners, managers, designers, engineers and contractors.* Wiley: Hoboken, NJ, c2011.2nd ed.

Gallagher, C.A. 1974. Perceptions of the value of a management information system. *Academy of Management Journal*, 17(1), 46-55.

Gavirneni, S., Kapuscinski, R. and Tayur, S. 1999. Value of Information in Capacitated Supply Chains. *Management Science,* 45(1), 16-24.

Giel, B. and Issa, R.R.A. 2016. Framework for Evaluating the BIM Competencies of Facility Owners. *Journal of Management in Engineering,* 32(1), 04015024.

Gu, N. and London, K. 2010. Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction*, 19(8), 988-999.

Howard, R. and Björk, B.-C. 2008. Building information modelling – Experts' views on standardisation and industry deployment. *Advanced Engineering Informatics,* 22(2), 271-280.

Kassem, M., Kelly, G., Dawood, N., Serginson, M. and Lockley, S. 2015. BIM in facilities management applications: a case study of a large university complex. *Built Environment Project and Asset Management,* 5(3), 261-277.

Kincaid, D. 1994. Integrated Facility Management. *Facilities,* 12(8), 20-23.

Klein, L., Li, N. and Becerik-Gerber, B., 2012. Imaged-based verification of as-built documentation of operational buildings. *Automation in Construction*, 21, 161-171.

Korpela, J., Miettinen, R., Salmikivi, T. and Ihalainen, J. 2015. The challenges and potentials of utilizing building information modelling in facility management: the case of the Center for Properties and Facilities of the University of Helsinki. *Construction Management and Economics*, 33(1), 3-17.

Neal, W. and Strauss, R. 2008. A Framework for Measuring and Managing Brand Equity. *Marketing Research*, 20(2), 6-12.

Parsanezhad, P. and Dimyadi, J. 2014. Effective Facility Management and Operations via a BIM-Based Integrated Information System. In: *CIB Facilities Management (CFM) 2014 Conference*, Copenhagen, Denmark:pp.8.

Patacas, J., Dawood, N., Vukovic, V. and Kassem, M., 2015. BIM for facilities management: evaluating BIM standards in asset register creation and service life. *Journal of Information Technology in Construction* (ITcon), 20(20), 313-331.

Perry, R.B. 1914. *The Definition of Value.*(6):141. [Online] Available from: http://search.ebscohost.com/login.aspx?direct=trueanddb=edsjsrandAN=edsjsr.10.2307.2013053andsite=eds-live[Accessed: 11/02/2016].

Repo, A.J. 1986. The dual approach to the value of information: an appraisal of use and exchange values. *Information processing and management*, 22(5), 373-383.

Volk, R., Stengel, J. and Schultmann, F. 2014. Building Information Modeling (BIM) for existing buildings – Literature review and future needs. *Automation in Construction,* 38(1), 109-127.

Wang, Y., Wang, X., Wang, J., Yung, P. and Jun, G. 2013. Engagement of Facilities Management in Design Stage through BIM: Framework and a Case Study. *Advances in Civil Engineering*. 2013.

Zhao, Y., Tang, L.C.M., Darlington, M.J., Austin, S.A. and Culley, S.J. 2008. High value information in engineering organisations. *International Journal of Information Management,* 28(1), 246-258.

BUILDING INFORMATION MODELLING (BIM) IMPLEMENTATION FOR MEP SYSTEMS IN BUILDINGS: A CONCEPTUAL FRAMEWORK

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ABSTRACT

The challenge in coordination of Mechanical, Electrical and Plumbing (MEP) systems is a common problem peculiar to the MEP industry. Although the traditional Two-Dimensional Computer Aided Design (2D CAD) has been used in the industry to resolve the problem of coordination, it has not been effective. Therefore, the aim of this paper is to develop a conceptual framework for Building Information Modelling (BIM) that can be implemented in the MEP Industry. This will facilitate a seamless transition to BIM and solve the MEP coordination problem of the traditional 2D CAD project delivery approach.

The conceptual framework was developed and refined through an extensive review of the literature concerning BIM. The framework developed is a model based collaboration framework that will allow MEP firms to collaborate to produce the coordinated construction model during the MEP coordination process. The framework has the potential to be used as a practical methodology for guiding the MEP firms that intend to implement BIM.

***Keywords**: Building Information Modelling (BIM); Construction Industry; Framework; Mechanical, Electrical and Plumbing (MEP).*

1. INTRODUCTION

The challenge in coordination of Mechanical, Electrical and Plumbing (MEP) systems is a common problem peculiar to the MEP industry. Although the traditional 2D CAD has been used in the industry to partially resolve the coordination problem, this has not been very effective. The process is done by manual superimposition, which is usually slow, time consuming and often results in project delay and increased project cost (Korman *et al.*, 2008). The 2D coordination process is highly fragmented and takes place on an as-needed basis (Korman *et al*., 2008). To overcome this situation, Building Information Modelling (BIM) facilitates easy coordination and collaboration during the design and construction stage.

BIM constitutes a paradigm shift in the construction project delivery approach in recent times. The benefits in terms of good return on investment (Smart Market, 2014), improved construction productivity and efficiency (Glick and Guggemos, 2009), increased coordination and collaboration (Autodesk, 2011) and reduced costly rework on projects (Smart Market, 2014) have been well established in the literature.

In view of the aforementioned, this paper intends to develop a conceptual framework for BIM implementation for the MEP building design and construction professionals in order to facilitate a seamless BIM transition and to solve the MEP coordination problem of the 2D project delivery approach.

2. LITERATURE REVIEW

MEP is an acronym that has been used historically to describe the mechanical, electrical, and plumbing systems in building and industrial projects. With an increase in the functionality and complexity of the systems, projects now include much more than just the traditional mechanical, electrical, and plumbing systems. The scope of

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the MEP activity has been extended to include additional systems, such as fire protection, controls, process piping, and telephone/data. Although these additional systems seem to fall under the historical categories of mechanical, electrical, and plumbing, they are most often installed by individual specialty contractors (Tatum and Korman, 1999).

The most common specification found in the design-bid-build contracts states that it is the MEP contractor's responsibility to coordinate the multiple building systems between the trades. Therefore, once the shop drawings have been produced, the coordination process begins. During this process, all the MEP contractors meet to determine the exact location of each system. This process becomes very intense as each system location is compared with each other system to determine where interferences and conflicts occur (Tatum and Korman, 1999).

2.1. LIMITATIONS OF THE TRADITIONAL 2D COORDINATION PROCESS

i. The Coordination is Slow and Expensive

Many problems exist with the current practice in the construction process. The construction teams need to meet a lot for coordination meetings. The coordination process is slow and expensive. The coordination of the MEP systems often delays the project and increases the cost for all those involved in the process. Coordination is often not budgeted for in the construction cost and remains a hidden cost in the design category. The sequential and iterative process is very slow because only slight progress is made at each meeting, and these coordination meetings consume valuable human resources (Korman *et al.,* 2008).

ii. The Coordination Process is highly fragmented.

Design and coordination take place on an as-needed basis and are often not performed sequentially. The desired scenario is for design changes to initiate coordination changes quickly and vice versa. Another complication is the lack of knowledge and understanding of the multiple disciplines involved, which often gives rise to systems that need redesigning to meet the coordination criteria (Korman *et al.,* 2008).

2.2. POTENTIAL OF BIM FOR IMPROVING MEP SYSTEM COORDINATION

There are many challenges to improving the current work process for coordination of the MEP systems. When performed manually, the coordination of the MEP systems requires considerable time from scarce experts, who have specialised knowledge about the design, construction, operation, and maintenance of the equipment systems. Building Information Modelling software is a new tool that provides the potential to improve the current work process for coordination of MEP systems (Korman *et al.*, 2008). BIM facilitates a new way of working: creating designs with intelligent objects. Regardless of how many times the design changes or who changes it, the data remain consistent, coordinated, and more accurate across all stakeholders. Cross-functional project teams in the building and infrastructure industries use these model-based designs as the basis for new, more efficient collaborative workflows that give all stakeholders a clearer vision of the project and increase their ability to make more informed decisions faster. Models created using software for BIM are intelligent because of the relationships and information that are automatically built into the model. The components of the model know how to act and interact with one another (Autodesk, 2011).

BIM tools have provided the feature to identify the clashes or collisions when integrating MEP systems with the architecture model and the structure model into one single platform (Wang *et al*., 2016). The visualization capabilities enable the specialty trades, designers and coordinators to review and detect these conflicts faster, better and more accurately (Wang *et al.,* 2016).

BIM models allow an inclusive and collaborative relationship to take place between all the interested parties, such as architects, engineers, consultants and contractors (Xia *et al*., 2011). Planners can select optimum sites. Architects can produce more accurate designs with fewer errors, less waste, and closer alignment to the owner’s vision. Engineers can increase coordination with the architects and other engineering disciplines, thereby improving the reliability of their design (Autodesk, 2011). The contractor can input their data and information into a collaborative process that becomes a part of an integrated construction model (Xia *et al.,* 2011). Contractors can make sure that constructability issues are flagged early on when changes are less expensive to make. Ultimately, owners will be able to use the models far into the future as the basis of a comprehensive facilities and asset management program (Autodesk, 2011).

BIM implementation requires proper planning, patience and full commitment from all levels of the organization. Successful BIM implementation within a company starts with the shared vision of change and buy-in from all members of the organisation. Senior leadership needs to support the change and be willing to sacrifice a little in the beginning to reap the future rewards (Infocomm, 2013). The key to success in any BIM project is the collaborative effort among all the team members, which includes, but is not limited to, the project owner, the design team, general contractor, subcontractors and vendors/suppliers. Information data must flow freely among all the BIM project team members to obtain maximum advantage in a BIM project. The project owner plays a central role in leading the discussion and decision-making process when it comes to applying BIM to his/her project (Infocomm, 2013).

3. RESEARCH METHODOLOGY

A conceptual framework was developed for the study through an extensive review of related literature concerning BIM from previous studies. The unique framework developed was adapted to suit the MEP Design-Bid-Build project delivery requirements. The main literature that was reviewed included referred academic journals, conference proceedings, BIM textbooks, trade publications and authorised courseware on BIM Revit MEP.

4. RESULTS AND DISCUSSION

The scope of this framework is a multidisciplinary model based collaboration framework that will allow MEP firms to collaborate to produce the coordinated construction model during the MEP coordination process. The framework is tailored towards the Design-Bid-Build project delivery method. The MEP Design and Build firms can also use this framework for their BIM based workflow, albeit there will be some changes in terms of design roles and responsibility.

This framework consists of six phases following the project life cycle approach. The overview of each phase is explained in the subsequent subsections and the overall framework is depicted in Figure 1. The full details of the framework are shown in Table 1.

4.1. AWARENESS PHASE

To successfully implement BIM in any organisation, awareness needs to be created. Awareness is required to gain the buy-in of all BIM stakeholders into the BIM strategic goals. The awareness phase starts with the identification of all BIM stakeholders, organising BIM awareness corporate training, developing a BIM business case and creating a BIM project charter that will authorise the start of a BIM project in an organisation. The details are shown in Table 1.

4.2. PLANNING PHASE

During the planning phase, an organisation will define how is going to successfully introduce and integrate BIM technology into its current system, and how to execute and control BIM activities at various developmental stages of the project life cycle. At the planning phase, two documents are developed*: the BIM Preliminary Assessment Plan and the BIM Execution Plan. The BIM Preliminary Assessment Plan* is used for internal decision-making purposes within the organisation that wants to make the transition to BIM. The plan contains a detailed assessment of the current process, technology and staff roles and responsibilities, identifying BIM requirements in terms of current and future needs, identifying the gaps between the current technology and skills inventory and the required BIM requirements, and making a concrete plan concerning how to fill the gaps. *The BIM Execution Plan* is used during the design and MEP coordination stages. It gives details of how BIM activities in those stages are planned, executed and controlled. It also forms part of the bidding award documentation issued to potential MEP contractors that will participate in BIM projects. The details of the Preliminary Assessment Plan and BIM Execution Plan are shown in Table 1.

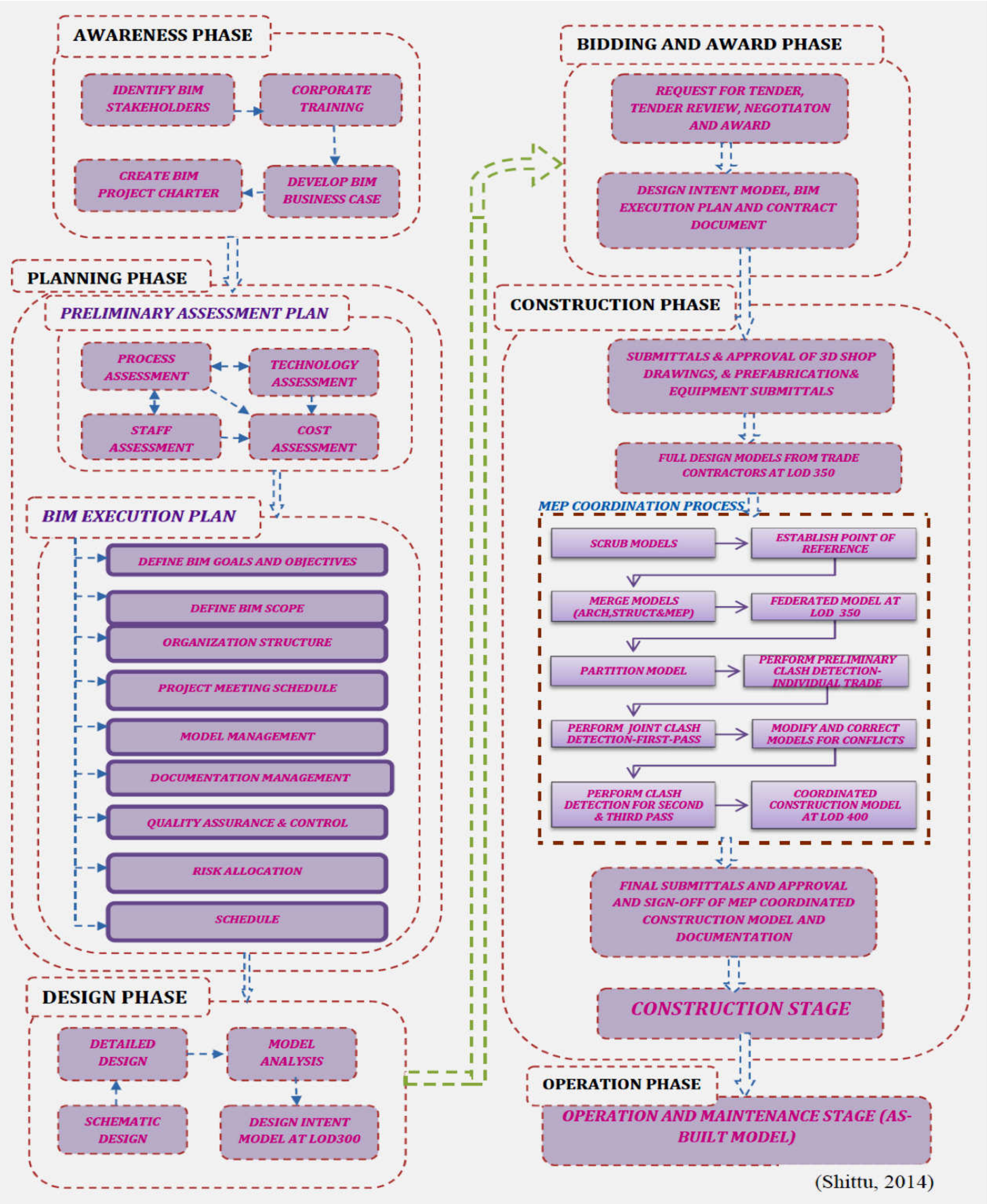

Figure 1: Conceptual Framework for BIM Implementation for MEP Systems in Building

Table 1: Details of Conceptual Framework for BIM Implementation

BIM PHASES	DETAILS	REFERENCE
1. AWARENESS PHASE **A. Identify BIM Stakeholders**	– Identify the potential BIM stakeholders that will support and drive the implementation of BIM in your organisation and from your clients; individual, private or public sectors	
B. Corporate Training	– The purpose is to create shared vision of change and buy-in from all members of the organisation. – Establish an affiliation with BIM experts, vendors or consultants – Organise BIM awareness corporate training to the top management, project sponsor and managers in your organisation. – Organise BIM awareness corporate training to the middle management and lower management in your organisation.	Infocomm, 2013
C. Develop BIM Business Case	– The business case captures the business need; it explains why the project was selected, how it fits into the organisation's strategic goals, and how it will bring business value to the organisation. – The purpose is to present the business value and cost benefit analysis to implement BIM, to your clients or project owners.	Mulcahy, 2013
D. Create BIM Project Charter	– Every project should have a project charter, so – BIM projects should not be an exception. – BIM charter will authorise the start of BIM project and gives authority to the Project Manager – It documents business needs, BIM objectives and initial requirements.	PMI, 2013
2. PLANNING PHASE **A. Preliminary Assessment Plan**	– This aspect of BIM planning gives a detailed review, analysis and assessment of the current process, technology and personnel. – It will identify the gap between what is existing and what is required to meet the current and future BIM requirements – Preliminary assessment plan will be used for internal purpose within an organisation for decision making on BIM requirements and implementation.	Quigley, 2013
I. Process Assessment	– Conduct detailed analysis of existing internal and external business processes. – Assessment of existing workflow in term of documentation process, data exchange and project information communication. – Determine the BIM based workflow requirements.	Infocomm, 2013
II. Technology Assessment	– This involves taking inventory of existing hardware, software and network facilities used by your organisation. – Determine the BIM software, hardware and network requirements. – Evaluate and select software, hardware and network server.	Quigley, 2013

BIM PHASES	DETAILS	REFERENCE
III. Staff Assessment	– This is a detailed personnel assessment of roles and responsibilities. – It answers the questions such as : – What are the current roles of your project teams? – Who will need to be trained with the new software? – What level of training will each type of employee require? – How will the new requirements of a BIM-based project modify the current make-up of your teams? – Create schedule of BIM roles and responsibilities for BIM projects. – Develop a schedule of BIM software product training for each staff that will participate in BIM project, based on their roles to play.	Infocomm, 2013
IV. Cost Assessment	– Prepare cost estimate for : • BIM hardware upgrade • BIM Software procurement • Network Server Upgrade • Product training for staffs	Infocomm, 2013
B. BIM Execution Plan	– The main purpose of BIM Execution Plan is to define and communicate the "rule of the road" to all participants in the coordination process.	Quigley, 2013
I. Define Goals and Objectives	– The BIM execution plan should define goals and objectives as they relate to the project. The BIM goals can be : – To improve communication between all stakeholders – To reduce the schedule of design and construction. – To improve design and field efficiency – To increase productivity	Quigley, 2013
II. Define Scope	– BIM execution plan will define scope of activities of BIM processes through different stages of project development. – Define the stage level of BIM to be implemented.(e.g. BIM stage 1 or 2 or 3) – Describe the deliverables to be produced at each phase of project lifecycle. – Define the Level of Development (LOD) for each domain-specific deliverables. – Describe the list of receivables that the design team will provide the coordination team.	Quigley, 2013 Quigley, 2013
III. Organisation Structure	– Identify the project participants for coordination process. – Define the required skills and responsibilities of each person. – Define the expected degree of involvement of each project participant including anticipated starting and disengagement point during the process. – Some of the Key BIM roles include: (a) **Project Coordination Manager**. His responsibilities include: • Managing the Coordination Team to ensure full participation and adherence to the BIM Execution Plan • Creating the coordination schedules. • Obtaining and distributing all contract drawings and documents, design change drawings and document and all CAD and Model files that the coordination team needs to create the initial models.	Quigley, 2013 Quigley, 2013

<table>
<tr><th>BIM PHASES</th><th>DETAILS</th><th>REFERENCE</th></tr>
<tr><td></td><td>
Acting as liaison between the Coordination Team and Architects, Engineers and Owner.
(b) Model Manager -His responsibilities include:

Setting up and maintaining a secure online files sharing site.
Assembling the initial master model
Setting up the initial file structure of the Model folders and establishing convention for naming project files.
Establishing elevations and the point of origin (insertion point) for all models.
Maintaining the model throughout the project.
Performing interference/clash - detection checks.
Generating clash detection reports.
Communicating information to the coordination team

(c) BIM Manager - His responsibilities shall include:

Managing the BIM processes
Supervising coordinators and detailers
Working internally with estimators, project management, and field personnel and externally with Architects, Engineers, General Contractor, Construction Managers, Trade contractors and Owners.
Establishing schedules and budgets.
Monitoring the processes to measure compliance with quality requirements and any other metrics established and defined by the organisation.
Filtering clashes and evaluating clash reports prior to coordination meeting.

(d) Detailers - His responsibilities shall include: - Detailing sections of the model.

Incorporating design-intent models, contract documents and specifications, and the project team's request and expectation into a virtual detailing model that represents the intended MEP installation for the building.
Understanding and interpreting architectural and structural details as they affect the MEP installations.
Identifying interferences with the architectural, structural and other MEP elements.
Generating contract and internal company deliverables from the models.

</td><td>Quigley, 2013

Quigley, 2013</td></tr>
<tr><td>IV. Project Meeting Schedule</td><td>
– BIM execution plan should provide basic information about project meetings

Which meetings are required? e.g. Kick-off, spatial planning meeting, coordination meeting and sign-off meeting.
When and where these meetings will be held?
Who is expected to attend and how often will be held?

</td><td>Quigley, 2013</td></tr>
</table>

BIM PHASES	DETAILS	REFERENCE
V. File format & compatibility (interoperability)	- List the electronic file formats (proprietary or open standard) that will be supported. - Identify the native files of project participants and do testing to confirm that the data files are compatible. - Adopt open-standard format for file sharing such IFC file format of Building SMART Alliance. - If a proprietary file format is specified in the contract, it should be clarified at the bidding phase.	Quigley, 2013
VI. Documentation Management (Configuration Management)	Documentation management in the BIM Execution plan should address the following: - Managing changes to the documentation about the deliverables and processes of the project. - Making sure every project team knows the latest version of project documentation. - Archiving documentation from BIM process • Complete version of the BIM data and associated deliverables should be copied into an archive location and stored as a record that should not be altered. - Setting up data security protocol • A data security protocol should be established to prevent any possible data corruption, virus infections and data misuse or deliberate damage by the project member, other employee or outside sources. • Adequate access right should be estimated to prevent data loss or damage during file exchange, maintenance and archiving. • BIM project data residing on the network server should be subjected to regular back-ups.	Mulcahy, 2013 Mulcahy, 2013 BCA, 2013 BCA, 2013
VII. Quality Assurance and Quality Control	- Quality Assurance and Quality Control is an integral part of BIM Execution Plan. The following activities should be considered in ensuring quality assurance and control in a BIM project : • Ensure that the model is created based on the modelling guidelines and CAD standards. • Ensure that the dataset are populated with correct data. • Detect any clashes between two building components using Clash Detection software. • Validation of BIM data to be used for Cross-Disciplinary Model Coordination:	BCA, 2013 BCA, 2013 BCA, 2013 BCA, 2013 BCA, 2013

BIM PHASES	DETAILS	REFERENCE
	– All drawing sheets and extraneous views should be removed from the BIM; – Each model file should be checked, purged and compressed; – Model files are up-to-date, containing all users' local modifications; – Model files are detached from central file; – Any linked reference files have been removed and any other associated data required to load the model file is made available; – Model is correctly assembled through visual inspection; – Any changes since the last issue are communicated to the project team.	BCA, 2013 BCA, 2013 BCA, 2013
VIII. Risk Allocation	– The BIM execution plan should clarify how risk will be allocated. The very nature of BIM introduces additional risks that must be allocated among the project participants. The liability of shared decision should also be clarified. – BIM Addendum specified that each party is responsible for any contribution made by them. – It also specified that each party agreed to waive claims against the other parties, over the Governing Contract for consequential damages arising out of, or relating to the use of access to a BIM Model.	Porwal and Hewage, 2013 Richard and Jason, 2010 Richard and Jason, 2010
IX. Schedule	– The BIM Execution plan should have a realistic schedule for the BIM Coordination process. – A detailed timeline is required to ensure that the overall strategy is being implemented in a timely and organised manner. – Coordination time should be factored into the project schedule. – Coordination should start after approval of submittals.	Infocomm, 2013 Quigley, 2013

4.3. DESIGN PHASE

During the design phase, BIM processes constitute a single disciplinary collaboration platform. The MEP design team jointly produces the design intent model that represents all the MEP Systems. The model is at the level of development (LOD) 300 (Quigley, 2013). The design intent model is detailed enough to prepare a tender or bid document. Table 2 shows the details of the BIM activities during the design phase.

4.4. BIDDING AND AWARD PHASE

During the Bidding and Award Phase, the tender or request for proposal documents produced during the design phase are used to prequalify MEP contractors through a competitive bidding process. After the bidding and negotiation process is completed, the selected MEP Contractors are issued the Contract documents, Design Intent Model and BIM Execution Plan.

4.5. *CONSTRUCTION PHASE*

During the construction phase, the major BIM activities comprise the MEP coordination process. The coordination starts very early during the construction phase immediately after the award of contract, and is completed before the actual construction starts. The selected MEP contractors use the design intent model issued with the contract award document to produce 3D Model fabrication shop drawings giving more details on the design intent model. It usually includes installation and prefabrication details at a level of development (LOD) 350. After completion of the shop drawings, they are sent for consultant approval along with other equipment submittals. The approved 3D Model shop drawings, which are now the full design model, are used during the coordination process.

Table 2: Details of Conceptual Framework for BIM Implementation

BIM PHASES CONT.	DETAILS	REFERENCE
3. DESIGN PHASE **I. Schematic Design**	– The details of design phase deliverables should be highlighted in the BIM Execution Plan. The deliverable shall include Design Intent Model and Bidding and Award documents. – Provide Schematic Modelling, analysing and system iterations as Design Model continues to develop	BCA, 2013
II. Detailed Design	– Create Discipline Specific Models and Analysis – Perform Preliminary Clash Detection – Finalise Discipline Specific Design Models, Tender documents and specification and code compliance.	BCA, 2013
4. BIDDING AND AWARD PHASE	– Send Request for Proposal or Tender to potential MEP Contractors – Perform Bidders' Conference for clarification on the tender documents. – Collect Contract responses and perform tender review. – Perform negotiation and select MEP contractors using the selection Criteria – Award contract and issue contract documents, design intent model at Level of details (LOD) 300 and BIM execution plan to successful Contractors	Mulcahy, 2013
5. CONSTRUCTION PHASE **I. 3 D Model Shop Drawing**	– Produce Full Design Model at LOD 350 through the 3D Model fabrication shop drawing.	

4.5.1 MEP COORDINATION PROCESS

For the development of this framework, we apply the definition given by the National Institute of Building Science (NIBS, 2013) for the spatial coordination process, and the guides from Quigley (2013) and Bokmiller, Whitbread and Hristov (2013) for the MEP coordination workflow. According to NIBS (2013), spatial coordination performed under contract is a collaborative process executed between the primary installation contractors and overseen by the general contractor or construction manager. This practice of spatial coordination seeks to integrate objects, systems, and components into spaces allocated in the contract documents. Quigley (2013) gave a summary definition of MEP spatial coordination, as a cooperative and collaborative effort between the design professionals, owner, general contractor or construction manager, and the trade contractors. Normal and expected spatial coordination performed by the trade contractors after the execution of contract is not design. Rather, it is a reflection of the design in a three-dimensional model. Trade contractors rely on complete and accurate designs when bidding for projects in order to provide an accurate bid price. In return, trade contractors using that design are able to produce reliable models from which the project can be constructed in a more efficient, timely and cost effective manner. The deliverable of the MEP coordination process will be a coordinated constructed model at LOD 400. This model will be used during the construction stage. The details of the MEP coordination process are shown in Table 3.

4.6. OPERATION PHASE

The operation phase starts after the completion of the construction, commissioning and handing over of the MEP system deliverables. The coordinated model used for construction is updated with any construction changes and used to produce the As-built model that is used during the operation and maintenance period of the project.

Table 3: Details of Conceptual Framework for BIM Implementation

BIM PHASES CONT.	DETAILS	REFERENCE
II. MEP Coordination Process Scrub Model	– Perform maintenance check on the design model by purging any unused items from the file to keep the file size minimum for easy sharing	Bokmiller *et al*., 2012
Establish Point of Reference	– Establish common point of reference before starting to link models – ON Revit MEP platform, it is recommended to use Auto-Origin to Origin of Positioning drop down menu of Import/LinkRVT dialog box to establish point of reference unless a shared coordinate system is required.	Bokmiller *et al*., 2012
Merge Models (MEP, Architectural & Structural)	– Merge Models to produce federated construction model at LOD 350.	Quigley, 2013
Perform Preliminary Clash	– Class detection can begin when all requirement of the BIM Execution Plan have been developed, reviewed and acknowledged by the coordination team, and a schedule for the program is developed and agreed.	Quigley, 2013
Detection - Individual Trade	– Individual trade should start with identifying and resolving clashes within their control	Quigley, 2013
Perform Joint Class detection –First Pass	– Best practices stipulate that the clash detection process for commercial facilities begins by resolving gross conflicts and work its ways to minor conflicts. – Non-movable systems, large-volume components (such as duct mains), and gravity system take precedence in space claiming and clash resolution. – Modify and correct Model for conflicts.	Quigley, 2013 Quigley, 2013
Perform Joint Clash detection - second and third pass	– The second pass identifies remaining conflicts, new conflicts created by addition of new support or seismic components into the model or non-resolved conflict from the initial pass – The third pass will identify and resolve the remaining conflicts.	Quigley, 2013
Coordinated Construction model at LOD 400	– The deliverable of MEP coordination process will be Coordinated Construction Model at LOD 400	Quigley, 2013
III. Construction Stage	– Coordinated Construction Model produced during the coordination process will be used during the construction stage.	
6. OPERATION PHASE	– The Coordinated Construction Model used for construction will be updated with any construction changes and used to produce As-Built Model that will be used during the operation and maintenance period of the project	

5. CONCLUSIONS

This research developed a conceptual BIM framework that will serve as a useful methodology for seamless transition from the traditional 2D CAD workflow to one that is BIM based and provides a solution to the problem of traditional 2D MEP Coordination. The framework developed emphasised the need for BIM awareness corporate and product training. Through the corporate training, more awareness about the potential of BIM will be created for all BIM stakeholders. Furthermore, it will allow the organisation to gain buy-in and support of their BIM stakeholders. Through the product training, BIM competency will be developed for the BIM project team.

The framework recommended developing a BIM preliminary assessment plan and BIM execution plan to overcome the challenges in the planning and executing BIM processes. Both plans will help the organisation to understand all the requirements needed to transition to BIM based workflow, monitor, and control BIM processes during the design and construction phase of project life cycle. This BIM framework will be of great benefit to the MEP firms where BIM implementation is still in the infant stage or even where there has been no transition to BIM. The framework can also serve as a checklist tool for those that had already transitioned to BIM based technology. It will help them for continuous improvement in their BIM processes and/or workflow.

To this end, it is noteworthy that this BIM framework developed is conceptual in nature. To ensure the practicability of the framework, it is therefore recommended that future research should be carried out to validate the framework to become a standard BIM framework in future for the MEP industry.

6. REFERENCES

Autodesk, 2011. *Autodesk Revit System: BIM for MEP Engineers* [online]. Available from: www.autodesk.com/bim [Accessed 23 December 2013].

Bokmiller, D., Whitbread, S. and Hristov, P., 2012. *Mastering Autodesk Revit MEP 2013* (1st ed.), Canada: John Wiley & Sons, Inc.

Building and Construction Authority (BCA), 2013. *Singapore BIM Guide Version 2.* Singapore: Building and Construction Authority. Available from www.bca.gov.sg [Accessed 20 January 2014].

Infocomm International, 2013. Building Information Modelling. USA, Available from http://www.infocomm.org/cps/rade/xchj/infocomm/hs.xsl/33591.htm. [Accessed 26 March 2014].

Glick, S. and Guggemos, A., 2009. IPD and BIM: Benefits and opportunities for regulatory agencies. *Proc., 45th Associated Schools of Construction National Conference*, Gainesville, FL.

Korman, T.M, Simonian, L. and Speidel, E., 2008. Using Building Information Modelling to Improve the Mechanical, Electrical, and Plumbing Coordination Process for Buildings. *AEI (2008): Building Integrated Solution. American Society of Civil Engineers (ASCE) database*, Available from http://www.ascelibrary.org [Accessed 20 March 2014].

Mulcahy, R., 2013. *PMP Exam Prep* (8th ed.), United States of America: RMC Publications, Inc.

National Institute of Building Sciences, 2013. Building SMART alliance, The National BIM standard United State, V2. *National Institute of Building Sciences,* available at www.nationalbimstandard.org [Accessed 25 February 2014].

Porwal, A. and Hewage, K.N., 2013. Building Information Modelling (BIM) partnering framework for public construction projects. *Automation in Construction,* 3, 204 – 214.

Project Management Institute, 2013. *A Guild to the Project Management Body of Knowledge* (5th ed.) Newton Square, Pennsylvania, U.S.A: Project Management Institute. Inc.

Quigley, D.E., 2013. *Achieving Spatial Coordination through BIM: A Guild for Specialty Contractors*. United States of America: Joint trade publication developed by Mechanical Contractors Association of America, Inc. (MCAA), The Mechanical Contracting Education and Research Foundation (MCERF), The National Electrical Contractors, Inc. (NECA), The New Horizons Foundation, and the Sheet Metal and Air Conditioning Contractors National Association (SMACNA).

Richard H.L. and Jason, M.M., 2010. *Consensus DOCS 301 BIM addendum, contracts forms and drafting/building information modelling*. [online] Consensus DOCS under license no 0405. Available from: www.consensusdocs.org/news/articles/bim [Accessed 20 February 2014].

Smart Market Report, 2014. *Business Value of Building Information Modelling*, [online] New York: McGraw Hill Construction. Available from: https://www.nibs.org/resource/resmgr/BSA/20140108_moa_jones.pdf [Accessed 20 March 2014].

Tatum, C.B., and Korman, T., 1999. *MEP coordination in building and industrial projects.* Stanford: Stanford University, CIFE Centre for Integrated Facility Engineering.

Wang, J., Wang, X., Shoua, W., Chong, H. and Guo, J., 2016. Building information modeling-based integration of MEP layout designs and constructability. *Automation in Construction,* 61, 134 – 146.

Xia, H., Tramel, J.M. and Shi, W., 2011. Building information modelling and simulation for the Mechanical, Electrical & Plumbing Systems. In *Proceeding of IEEE International Conference, Computer Science and Automation Engineering (CSAE)*, 3, 77-80.

CARBON HOTSPOTS OF OFFICE BUILDINGS IN THE UK

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ABSTRACT

Embodied carbon of buildings is receiving substantial attention due to the increasing statutory requirements on operational carbon of buildings. Even though the embodied carbon of buildings is not regulated at present there is a need to control embodied impacts of buildings because embodied carbon of buildings tends to increase as the operational carbon savings increase. Focusing on intensive emissions sources or the hotspots is an effective way of managing embodied carbon during the early stages of design though there is a gap with regards to the knowledge of carbon hotspots. Therefore, embodied carbon estimates of 28 office buildings in the UK were obtained and the carbon hotspots of buildings (in accordance with NRM element classification) were identified using the 80:20 Pareto Principle. Frame, Substructure, External walls, Services and Upper Floors were identified as carbon hotspots of the sample. However, findings do not support the 80:20 ratio in this case but propose a ratio of 80:36. In addition, the building elements were categorised into three types based on the probability of each element is being identified as a hotspot in the sample which is referred to as the 'carbon hotspot probability'. The elements that were categorised as 'Lead Positions' and 'Special Positions' are the elements with higher reduction potential compared to remainder positions and require more attention during the early stages of design to achieve maximum reduction in embodied carbon.

Keywords: *Carbon Hotspots; Embodied Carbon; Office Buildings; Pareto Principle.*

1. INTRODUCTION

A rise in the number of low and zero carbon buildings is evident in most developed countries as a result of stringent statutory requirements imposed on operational carbon of buildings. However, operational carbon reduction measures likely to make Embodied Carbon (EC) of buildings relatively more important which are unregulated at present. The reduction potential of EC is higher during the early stages of design compared to the latter and more detailed stages (RICS, 2014). The reduction potential decreases increasingly as more carbon is committed to the project due to the fact that the possible design solutions are constrained by previous design decisions. However, tools and techniques to manage EC during the early stages of design are still in their infancy. In fact, estimating EC during the early stages of design is challenging due to limited design information. However, it has been proposed that focusing on intensive emission sources would be one good approach for achieving high carbon reduction or to reap benefits during the early stages of design (Carbon Trust, 2010, RICS, 2014, Halcrow Yolles, 2010). These carbon intensive elements are referred to as 'carbon hotspots' in this paper. The paper introduces the concept of carbon hotspots and the importance of capturing carbon hotspots by presenting two case studies from the literature. The rationale for choosing 80:20 Pareto Principle for identifying the carbon hotspots is discussed in the research method. The carbon hotspots of the sample are presented in data analysis and discussion and the elements with high reduction potential were identified and reported.

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2. LITERATURE REVIEW

Carbon hotspots of buildings are the elements which are carbon significant, easily measurable and with high reduction potential (RICS, 2014). Hence, identifying hotspots is crucial to reduce embodied carbon impacts of building designs right from the early stages of design. These carbon hotspots may vary from one building to another depending on the type or the function of the building (Ashworth and Perera, 2015; Perera and Victoria, 2017) due to differing element intensities. However, the knowledge about carbon hotspots is not flagged yet and is still developing.

Monahan and Powell (2011) highlighted the importance of identifying hotspots in buildings by modelling a two-storied residential building (in the UK) in three different scenarios; timber frame and larch cladding, timber frame and brick cladding, conventional masonry cavity wall. The substructure (including foundation and ground floor) accounted for 50% of embodied carbon in timber frame and larch cladding building and substructure, external walls and roof were identified as carbon hotspots of the building (elements responsible for 81% of embodied carbon, however, not all the building elements were included in the accounting). Further, the same building (timber frame with larch cladding) substituted with timber frame and brick cladding and conventional masonry resulted in additional embodied carbon of 32% and 51% respectively. The majority of the difference in embodied carbon was found to be attributed to the difference in foundations and external walls. The findings of the study (Monahan and Powell, 2011) identify the substructure and external walls as ‘carbon hotspots’ in the case study building and showcase the potential for embodied carbon reduction.

Shafiq *et al.* (2015) studied a two-storied office building in Malaysia by modelling six different scenarios for structural composition using Building Information Model (BIM). However, Shafiq *et al*. (2015) used UK databases to estimate embodied carbon due to lack of embodied carbon databases in Malaysia. Different grades or classes of concrete and steel were combined to generated different composition, which resulted in different material quantities producing varying embodied carbon impacts. Only a few elements were studied including foundation, beams, slabs, columns and staircases, which can be related to the Substructure, Frame, Upper Floors and Stairs as per the New Rules of Measurement (NRM) element classification. Shafiq *et al*. (2015) found that it was possible to reduce up to 31% of embodied carbon by designing these elements with different classes of concrete and steel to meet the given design criteria. However, it should be noted that only the structural elements have been considered in this study.

It is clear that embodied carbon studies in different types of buildings highlighted above (Monahan and Powell, 2011; Shafiq *et al*, 2015) have different focuses and hence, limit the analysis mainly to structural and facades. However, Cole and Kernan (1996) found that cladding finishes and services are to be the biggest component of recurring embodied carbon emissions of an office building and services can account for 10-25% of total embodied carbon emissions (Hitchin, 2013; RICS, 2014). This implies that finishes and services are also embodied carbon significant elements though these are based on a few case studies. Hence, a holistic analysis of typical buildings will paint a complete picture on the embodied carbon contributions of each element and will highlight the potential areas of embodied carbon reduction.

3. RESEARCH METHOD

Embodied carbon estimates of 28 office buildings that are in accordance with the NRM compliant element classification standard were obtained from a QS consultancy practice in the UK. The estimates were produced using Bills of Quantities (BOQ) of buildings and published sources of embodied carbon emission factors such as Inventory of Carbon and Energy (ICE) (Hammond and Jones, 2011) and the UK Building Blackbook (Franklin and Andrews, 2011). The obtained sample consisted of steel, concrete and hybrid framed buildings ranging from one (1) to thirty-six (36) storeys and the Gross Internal Floor Area (GIFA) of buildings ranges from 1,788 m^2 to 130,930 m^2. The profile of the sample suggests that there is a correlation between the number of storeys and the GIFA of buildings. However, a similar pattern was not displayed between the GIFA and the EC per GIFA of buildings (see Figure 1). This suggests that EC per GIFA of buildings are not influenced by GIFA itself, even though there is a relationship between the total embodied carbon and the building size due to increased element quantities. Therefore, this justifies the use of a sample containing a wide spectrum of GIFA.

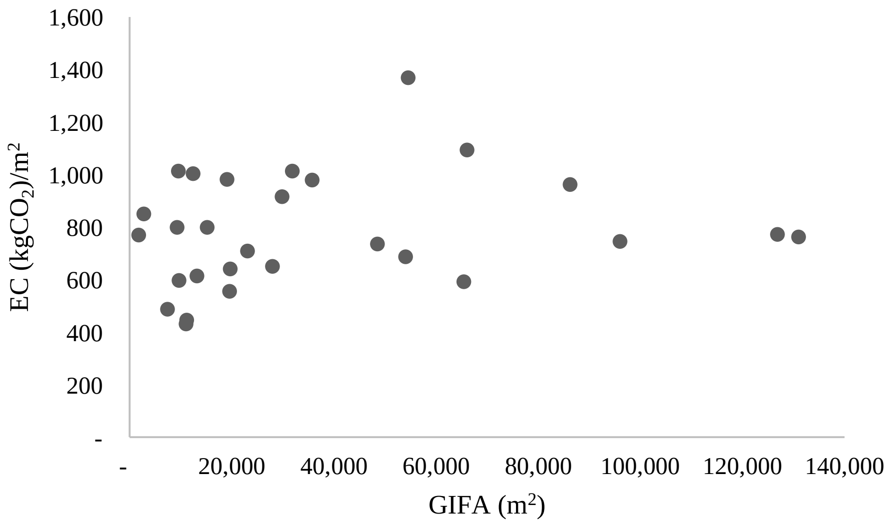

Figure 1: Plotting EC per GIFA against the GIFA of Buildings

The embodied carbon estimates have a system boundary of cradle-to-gate which includes the embodied carbon associated with the material manufacturing (raw material extraction up to the manufacturing factory gate). The carbon significant elements or the carbon hotspots were identified for the whole sample using the 80:20 Pareto Principle. Pareto Principle proposes that 80% of the results (or consequences) are attributable to 20% of the causes which implies an unequal relationship between the inputs and the outputs (Koch, 2011; Delers, 2015). Munns and Al-Haimus (2000) noted that the seminal texts in the cost management literature (Ashworth and Perera, 2015; Seeley, 1996; Ashworth and Skitmore, 1983) acknowledging the applicability of Pareto Principle to identify the cost significant items. Further, the works of Munns and Al-Haimus (2000) and Tas and Yaman (2005) are examples of embracing 80:20 Pareto Principle to identify the cost significant items of buildings and eventually, developing prediction models. Hence, Pareto Principle was adopted to identify carbon significant elements of buildings which are the elements contributing up to 80% of the total embodied carbon. Consequently, the 80:20 Pareto ratio was verified in the context of embodied carbon of building.

In addition, some building elements are more critical than the others and have higher reduction potential. Hence, carbon hotspots of each building were identified and the probability of each element is being identified as a carbon hotspot in the whole sample was calculated using the formula for probability calculation presented in Eq. 1.

$$P_i = \frac{n_i}{N} \qquad \textit{(Eq. 1)}$$

Where, P_i is the carbon hotspot probability of the respective element, n_i is the frequency of the respective element being identified as a hotspot in the whole sample and N is the sample size or the total number of buildings considered, which is 28.

Based on the carbon hotspot probability, the building elements were categorised into three types such as ‘Lead Position’, ‘Special Position’ and ‘Remainder Position’. The description of each category is as follows:

i. Lead positions: Carbon hotspot probability > 0.8)
ii. Special positions: Carbon hotspot probability 0 - 0.8)
iii. Remainder positions: Carbon hotspot probability = 0)

Accordingly, ‘Lead Positions’ were the elements that were frequently identified as carbon hotspots; ‘Special Positions’ were the elements identified as hotspots occasionally, and ‘Remainder Positions’ are the elements that were not identified as hotspots. In addition, the reduction potential of each element was conceived based on their carbon hotspot category. Lead positions were regarded as elements with high reduction potential due to their significant contribution to the total embodied emission while special positions were classed as elements with medium reduction potential due to their wavering nature in the hotspot category. Alternatively, the reduction potential of remainder positions was considered to be low due to their marginal contribution to the total embodied emissions.

4. DATA ANALYSIS AND DISCUSSION

The descriptive statistics of the whole sample is presented in Table. Accordingly, the EC per GIFA of office buildings ranges from 432 $kgCO_2/m^2$ to 1,368 $kgCO_2/m^2$ with an average of 785 $kgCO_2/m^2$. The confidence interval of the sample was found to be 80 which implies that it can be inferred with 95% confidence that the population mean (EC per GIFA) will lie between ±80 $kgCO_2/m^2$ from the sample mean (EC per GIFA) which is 785±80 $kgCO_2/m^2$. This statistic suggests that the sample mean can be used to predict EC per GIFA of a proposed building with 90% accuracy (±10% deviation in the prediction) which is acceptable for an early stage estimate (See, Ashworth and Skitmore, 1983).

Table 2: Descriptive Statistics of Elemental EC per GIFA of the Sample

Element	Average of the EC per GIFA ($kgCO_2/m^2$)	Minimum	Maximum	Standard Deviation
1A Substructures	137.20	33.21	320.72	65.31
2A Frame	236.72	98.00	486.41	101.13
2B Upper floors	75.99	1.72	191.08	38.68
2C Roof	25.05	2.88	103.25	19.69
2D Stairs	7.00	2.47	21.46	5.01
2E External walls	111.24	8.37	265.80	63.35
2F Windows and external doors	15.20	0.02	157.64	35.20
2G Internal walls and partitions	20.14	1.19	64.37	15.97
2H Internal doors	1.50	0.12	7.32	1.79
3A Wall finishes	3.65	0.22	18.47	4.23
3B Floor finishes	37.69	0.39	97.77	28.82
3C Ceiling finishes	8.55	0.65	24.62	6.05
4A Fittings and furnishings	0.86	0.02	3.39	1.15
5 Services	106.81	6.63	192.88	50.16
EC per GIFA	**785.31**	**431.61**	**1368.17**	**215.92**

Table 3 presents the carbon hotspot analysis of the sample with percentage contributions of each element and the cumulative percentage of the group. Frame, Substructures, External walls, Services and Upper Floors were identified as carbon hotspots (elements contributing up to 80% of EC) of office buildings in descending order of significance. In particular, Frame contributes up to 30% of EC of office buildings as concrete and steel which are main framing materials are high carbon intensive. Next, Substructure, External Walls and Services are contributing almost equally towards the total EC of buildings. The most common foundation type includes raft and pile which involves high usage of concrete, steel and machinery resulting in high EC contribution. Similarly, curtain walling being the most common External Wall type in offices in the UK makes External Walls a hotspot. Hence, the use of recycled concrete and steel, low energy intensive production methods, light pre-fabricated elements, recycled glass and low carbon façades such as bio-based materials and re-use of materials (Lupíšek *et al*., 2015) will contribute towards EC savings. Furthermore, it can be noticed from Table that five out of fourteen elements are contributing up to 80% of the total EC, alluding a new ratio which is 80:36 in the context of EC of office buildings.

Table 3: Carbon Hotspot Analysis of the Sample

Element (NRM compliant)	Average EC per GIFA ($kgCO_2/m^2$)	Element contribution %	Cumulative %
2A Frame	236.72	30.1%	30.1%
1A Substructure	137.2	17.4%	47.5%
2E External Walls	111.24	14.1%	61.6%
5 Services	106.81	13.6%	75.2%

Element (NRM compliant)	Average EC per GIFA ($kgCO_2/m^2$)	Element contribution %	Cumulative %
2B Upper Floors	75.99	9.6%	84.8%
3B Floor finishes	37.69	4.8%	89.6%
2C Roof	25.05	3.2%	92.8%
2G Internal Walls and Partitions	20.14	2.6%	95.3%
2F Windows and External Doors	15.2	1.9%	97.3%
3C Ceiling Finishes	8.55	1.1%	98.3%
2D Stairs	7	0.9%	99.2%
3A Wall Finishes	3.65	0.5%	99.7%
2H Internal Doors	1.5	0.2%	99.9%
4A Fittings and Furnishings	0.86	0.1%	100.0%

Table 4 presents the carbon hotspot category of each element based on the probability of occurrences in the sample and their emission reduction potential. Accordingly, Frame has been identified as a hotspot in all the buildings. Substructure and Services were identified as hotspots in 90% of the buildings and External Walls were identified as a hotspot in 80% of buildings making Frame, Substructure, Services and External Walls 'Lead Positions'. These are the building elements with higher reduction potential. On the other hand, Stairs, Internal Walls and partitions, Internal Doors, Wall Finishes, Ceiling Finishes and Fittings and Furnishings were not found as hotspots in any of the buildings making it 'Remainder Positions' and building elements with lower reduction potential. The rest (Upper Floors, Roof, Windows and External Doors and Floor Finishes) were identified as 'Special Positions' with medium reduction potential. This analysis showcases the building elements which are more critical than others in term of EC contribution and where most of the reduction can be achieved. Similarly, it also highlights the elements which are EC insignificant with lower reduction potential. It is clear from the findings above that building design determines the chances of an element being a hotspot in a particular building. Therefore, the design of 'Lead Positions' and 'Special Positions' can play an important role in influencing the embodied carbon accountability of buildings.

Table 4: Carbon Hotspot Category

Elements	n_i	P_i	Element Category	Reduction Potential
1A Substructures	25	0.9	Lead	High
2A Frame	28	1	Lead	High
2B Upper Floors	17	0.6	Special	Medium
2C Roof	4	0.1	Special	Medium
2D Stairs	0	0	Remainder	Low
2E External Walls	21	0.8	Lead	High
2F Windows and External Doors	3	0.1	Special	Medium
2G Internal Walls and Partitions	1	0	Remainder	Low
2H Internal Doors	0	0	Remainder	Low
3A Wall Finishes	0	0	Remainder	Low
3B Floor Finishes	5	0.2	Special	Medium
3C Ceiling Finishes	0	0	Remainder	Low
4A Fittings and Furnishings	0	0	Remainder	Low
5 Services	24	0.9	Lead	High

5. CONCLUSIONS

The aim of the paper was to capture the carbon critical elements or the carbon hotspots of office buildings and identify the building elements with emission reduction potential. 80:20 Pareto Principle was adopted to identify the carbon hotspots and the ratio was also verified in the case of embodied carbon of buildings. Accordingly, Frame, Substructures, External walls, Services and Upper Floors were identified as carbon hotspots of office buildings and the findings suggest that 36% of the elements are responsible for 80% of the embodied carbon impacts of buildings proposing an 80:36 ratio. Frame, Substructure, Services and External Walls were identified as the elements with high emission reduction potential while Upper Floors, Roof, Windows and External Walls and Floor Finishes were identified to have medium emission reduction potential. Elements including Stairs, Internal Walls and partitions, Internal Doors, Wall Finishes, Ceiling Finishes and Fittings and Furnishings can be disregarded in the design decision-making during the early stages of design due to their minimal or almost negligible emission reduction potential. The findings display the significance of the design of building structure, façade, finishes and services in influencing the embodied carbon of buildings while suggesting that the highest reduction potential is achievable in the structure, façade and services of office buildings. Emission reductions can be achieved in the structure by using recycled concrete/steel and light pre-fabricated elements, re-use of materials and selecting low energy intensive production and operations; use of recycled glass and low carbon façade such as bio-based materials can bring savings in the façade embodied carbon. However, opportunities for reducing embodied carbon in services are limited which calls for in-depth research in this area.

6. References

Ashworth, A. and Perera, S. 2015. *Cost studies of buildings.* Oxon: Routledge.

Ashworth, A. and Skitmore, R. M. 1983. Accuracy in Estimating. *CIOB Occasional Paper No. 27.* London: CIOB.

Carbon Trust, 2010. *Carbon: Reducing the footprint of the construction process*. UK: Carbon Trust.

Cole, R. J. and Kernan, P. C. 1996. Life-cycle energy use in office buildings. *Building and Environment,* 31**,** 307-317.

Delers, A. 2015. *Pareto's Principle: Expand your business!*. Belgium: 50Minutes.com.

Franklin and Andrews 2011. *Hutchins UK building blackbook: the cost and carbon guide: hutchins' 2011: Small and Major Works*, Croydon, Franklin and Andrews.

Halcrow Yolles 2010. *Sustainable offices – embodied carbon*. UK: South West Regional Development Agency.

Hammond, G. and Jones, C. 2011. *A BSRIA guide to embodied carbon: the inventory of carbon and energy*. UK: BSRIA.

Hitchin, R. 2013. *CIBSE Research Report 9: Embodied Carbon and Building Services*. UK: CIBSE.

Koch, R. 2011. *The 80/20 Principle*. London: Nicholas Brealey Publishing.

Lupíšek, A., Vaculíková, M., Manľík, Š., Hodková, J. and Růžiľka, J. 2015. Design Strategies for Low Embodied Carbon and Low Embodied Energy Buildings: Principles and Examples. *Energy Procedia,* 83**,** 147-156.

Monahan, J. and Powell, J. C. 2011. An embodied carbon and energy analysis of modern methods of construction in housing: A case study using a lifecycle assessment framework. *Energy and Buildings,* 43**,** 179-188.

Munns, A. K. and Al-Haimus, K. M. 2000. Estimating using cost significant global cost models. *Construction Management and Economics,* 18**,** 575-585.

Perera, S. and Victoria, M. 2017. The role of carbon in sustainable development. *In:* LOMBARDI, P., SHEN, G. Q. and BRANDON, P. S. (eds.) *Future challenges for sustainable development within the built environment.* UK: Wiley's Publication.

RICS. 2014. *Methodology to calculate embodied carbon*. 1 ed. UK: RICS.

Seeley, I. H. 1996. *Building economics: appraisal and control of building design cost and efficiency.* Basingstoke: Macmillan.

Shafiq, N., Nurrudin, M.F., Gardezi, S.S.S. and Kamaruzzaman, A.B., 2015. Carbon footprint assessment of a typical low rise office building in Malaysia using building information modelling (BIM). *International Journal of Sustainable Building Technology and Urban Development*, 6(3), 157-172.

Tas, E. and Yaman, H. 2005. A building cost estimation model based on cost significant work packages. *Engineering, Construction and Architectural Management,* 12**,** 251-263.

CAUSES OF ACCIDENTS IN HIGHWAY CONSTRUCTION PROJECTS IN OMAN

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ABSTRACT

Construction workers are three to four times more likely than workers in other sectors to die from accidents at work. Construction is one of the main industries in Oman providing jobs to 18% of the total population and contributing around 10% of the total Gross Domestic Product (GDP). Considering the costs associated with accidents in construction, a model identifying the root causes of accidents is proposed for construction organizations in Oman. The model classifies the accidents in construction mainly arising from main four causes: "Equipment / Materials", "Workers", "Environment" and "Management". The model is applied to a road construction project in Oman to trace the root causes of accidents. It can also be applied to construction projects in other sectors such as building or process plant construction. The results of this investigation reveal that a substantial proportion of accidents (more than 41%) arise from the "Worker". The Management contribution is 31%, Equipment/Materials contribute 14% to the accidents and the Environment contribution is 12%. These findings are based on accident statistics that occurred on a single road project. Further research is recommended to extend the study to other projects in the construction sector in order to generalize the findings. Knowing the root causes of accidents will help organizations to develop effective strategies to reduce accidents in future projects. Although the frequency distribution of accidents is likely to vary from project to project, understanding the underlying pattern of their causes helps to pinpoint the key areas where resources should be directed in the organizations' efforts to deliver the goal of zero accidents.

Keywords: *Construction Hazards; Health and Safety; Management.*

1. INTRODUCTION

Worldwide occupational injury rates in the construction sector are high compared with all other major industries (Lehtola *et al*., 2008). Unlike other industries such as manufacturing, construction is composed of a transient workforce (Dubois and Gadde, 2002; Kadefors, 1995), where project personnel from different cultures and backgrounds are expected to work together in a constantly changing work organization and structure. Construction is always risky due to outdoor operations, work at height, complicated on-site plant machinery and equipment operations coupled with the worker's attitudes and behaviours towards safety (Choudhry *et al*., 2007). Statistics published by the International Labor Organization (ILO, 2016, n.d) indicate that at least 108 000 workers are killed on construction sites every year, a figure that represents about 30% of all fatal occupational injuries. Data from a number of industrialized countries show that construction workers are three to four times more likely than other workers to die from accidents at work. In the developing world, the risks associated with construction work may be three to six times higher. Accidents include not only direct physical injury to persons or damage to property, but also short and long term effects or incidents due to other exposures on sites that affect the workers' health and physical well-being. The costs of accidents (direct and indirect) can be substantial. The costs of accidents in the USA were determined as 6.5% of the total value of completed work and in the UK it is approximately 8.5% of the tender value (BRT, 1995; Anderson, 1997). Research conducted in the UK on cost and benefit analysis revealed that when total costs of accident prevention

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were compared to the total benefits of accident prevention, the benefits far outweigh the costs of accident prevention by a ratio of approximately 3:1, which means that when contractors, irrespective of their sizes, spend £1.00 on accident prevention, they gain £3.00 (Ikpe *et al* 2012). The cost of accidents can be understood by contractors and represents a tangible measure that can be related to project financial accounts and both the income statement and balance sheet of a contractor (Tang *et al*. 2004; Booth and Panopoulos 2005). The costs of accident also affect the workers and society, as illustrated in Table 1. Thus, this category of cost is very often at the forefront of considerations of the costs of health and safety.

Table 1: Costs of Accidents Incurred by Stakeholders (Ikpe *et al.*, 2012)

Stakeholders	Intangible Costs	Tangible Costs
Worker	Pain and suffering, moral and psychological suffering (especially in the case of death and permanent disability)	Loss of salary, reduction of professional capacity, loss of time (medical treatment), site compliance of health, and safety issues
Family and friends of the affected worker	Moral and psychological suffering, medical and family burden	Financial loss, extra costs, loss of time to take care of the injured worker
Coworkers	Bad feeling, worry, or panic (in case of serious or frequent accidents)	Loss of time, increase of workload, and training of temporary staff
Employer	Bad reputation, litigation cost, insurance cost, and compensation cost	Decrease in production; damages to machinery, equipment, and material; quality losses; recruitment and training of new staff; increase of production costs; increase of insurance premium; administrative costs; litigation costs; and absenteeism
Society	Reduction of the human labor potential, and reduction of the quality of life	Loss of production, increase of social costs, medical treatment and rehabilitation costs, and decrease of standard of living

Construction is a major industry providing jobs to millions of people and contributing to countries and the world economy. Contribution towards the Omani economy is around 10% of the total GDP and employs 18% of the total population (NCSI 2015). Oman labour law empowers the ministry of manpower to ensure the health and safety standards through ministry inspectors and in event of the existence of any danger which threatens the safety and health of the workers, the Ministry can take necessary measures to close down the place of work wholly or partially, or to stop the operation of one or more machinery until the elimination of the causes of such danger. The ministry could improve further the process of inspections and penalties by benchmarking its system with OSHA (USA) and HSE (UK).

Knowing the root causes of accidents can help construction organizations in preventing accidents in future through appropriate risk mitigation measures and by addressing the weak areas associated with accidents. This paper aims to develop a model for identifying the root causes of accidents in construction. The focus of the paper is on highly construction projects in Oman. The root causes of accidents are broadly divided into four categories: equipment / materials, workers, environment and management. The model described in this article will help construction organizations in Oman to identify the root causes of accidents which will further help the construction organizations in developing strategies to reduce accidents on construction sites.

2. LITERATURE REVIEW

Construction researchers have proposed several accident causation models and root causes. McClay's (1990) "universal framework" identified three key elements of accidents: hazards, human actions, and functional limitations. Hinze's (1996) distraction theory argued that production pressures can distract workers from the hazards and increase the probability of accidents. Abdelhamid and Everett (2000) identified management deficiencies, training, and workers' attitude as the three general root causes. The "constraints-response" model by Suraji *et al.* (2001) argues that project conditions or management decisions can cause responses that create inappropriate conditions or actions that lead to accidents. Gibb et *al.* (2006) identified worker, workplace, material and equipment as shaping factors of accidents in construction. The Accident Root Causes Tracing

Model (ARCTM) presented by Abdelhamid and Everett (2000) discussed four main causes of accidents that are from;

- Management actions / inactions
- Unsafe acts of worker or co-worker
- Non-human related events
- An unsafe condition that is a natural part of initial construction site conditions.

The model proposed by Mitropoulos (Mitropoulos *et al*. 2005) identifies the need for two accident prevention strategies: (a) reliable production planning to reduce task unpredictability, and (b) error management to increase the workers' ability to avoid, trap, and mitigate errors. A study into the causes of accidents in the construction industry in Uganda linked the major causes of accidents in construction to inadequate supervision, use of incompetent personnel and use of inappropriate construction techniques (Lubega *et al.* 2000). The research concluded that accidents are caused by a wide range of factors including;

- Lack of awareness of safety regulations
- Lack of enforcement of safety regulations
- Poor regard for safety by people involved in construction projects
- Engaging incompetent personnel
- Non-vibrant professionalism
- Mechanical failure of construction machinery/equipment
- Physical and emotional stress
- Chemical impairment.

Research conducted by Hamid *et al*. (2008) in Malaysia on the causes of accidents on construction sites concludes that the main cause of construction accidents are workers' negligence, failure of workers to obey work procedures, work at high elevation, operating equipment without safety devices, poor site management, harsh work conditions, low knowledge and skill level of workers, failure to use personal protective equipment and poor workers attitude about safety.

Haslam *et al*. (2005) in their studies of 100 individual construction accidents summarized the levels of involvement of key factors in the accidents as: problems arising from workers or the work team (70% of accidents), workplace issues (49%), shortcomings with equipment-including PPE (56%), problems with suitability and condition of materials (27%), and deficiencies with risk management (84%). They further suggest that design and cultural factors shape the circumstances found in the work place, giving rise to the acts and conditions which, in turn, lead to accidents. It is argued that attention to the originating influences will be necessary for sustained improvements in construction safety to be achieved.

Research on the causes and effects of accidents on construction sites conducted Nigeria found that workers are the major contributors to the causes of accidents on construction sites, which ranges from 53% to 67% of the main causes of accidents in different sizes of construction organization. Although there are further 25 different factors which contribute to accidents on construction sites, the research also concludes that workers are the most affected people from accidents whatever the cause (Kadiri *et al* 2014).

The study by Ali *et al*. (2010) reveals that accidents are generally caused by unsafe acts and unsafe conditions besides other sub-causes. Accidents can result from a combination of contributory causes. The main causes of construction accidents identified in their study are the human element, poor site management, failure to use personal protective equipment and unsafe equipment used in construction work.

Based on the above literature review the proposed model for tracing the root causes of accidents discussed in this article classify the accidents arising from four main causes that can be related to;

- Equipment / Materials
- Worker
- Environment
- Management

3. RESEARCH METHODOLOGY

The methodology adopted in this research includes the collection of actual accidents data from a construction organization that just completed a major highway project. Five main construction organizations that were involved in delivering the project were asked for cooperation to investigate the root causes of accident on the project. These organizations were informed about the purpose of the research and the information required for the purpose of the research. Only one construction organization agreed to cooperate on the condition that the name of the organization would not be revealed. This construction organization was carrying out a 75km road construction project estimated to cost of US $ 305.90 million. The project was started in September 2011 and 82 % of the work was completed in April 2016. The data collection includes the interviews with the HandS team along with the review of documentary records of the accidents take place in the project. The accidents data was collected directly from the project HandS team and included following information.

- Type, nature and location of accident
- Statement of workers involved in the incident
- Report of the safety or site supervisor
- Photos of the accidents
- Medical reports in case of medical injury

A total of 623 accidents data was provided by the HandS team. These accidents were of different types in nature. Based on the accident data, the different types of accidents were initially classified based on their nature under:

3.1. ALTERNATE WORK INJURY (AWI)

A work injury that results in the injured person being able to perform only restricted (light) duties in the original workplace on the first scheduled work day or shift (or any subsequent work day or shift) on the day after the incident.

3.2. FIRST AID INJURY (FAI)

A work injury that requires first aid treatment, including observations, TT (Tetanus Toxoid) injections, non-prescription drugs, pain killers, examination, x-rays, oral rehydration, minor dressings even if carried out in the hospital.

3.3. LOSS TIME INJURY (LTI)

A work injury or disease resulting in a fatality, permanent disability or time lost from work of one or more complete work days or shifts, following the fourth day or shift of the incident. Fatalities causes from suicide or natural causes are excluded.

3.4. MEDICAL TREATMENT INJURY (MTI)

A work injury that requires treatment other than first aid at a hospital or other medical facility.

3.5. PROPERTY / EQUIPMENT DAMAGE

These are incidents resulting from workplace activities that caused damage to property or equipment only.

To find the root causes of these incidents a model was developed to identify the causes of accidents and to relate them to the main causes from Material / Equipment, Workers, Environment and Management as shown in the Table 4. These main causes of accidents were identified from a literature review on different models of the root causes of accidents in construction. Each cause of accident is supported by different statements (Table 4). To trace the causes of accidents, each accident is review against the statements of particular cause of accidents shown in Table 4.

The process used in this research to identify the root causes of accidents in construction is explained in Figure 1.

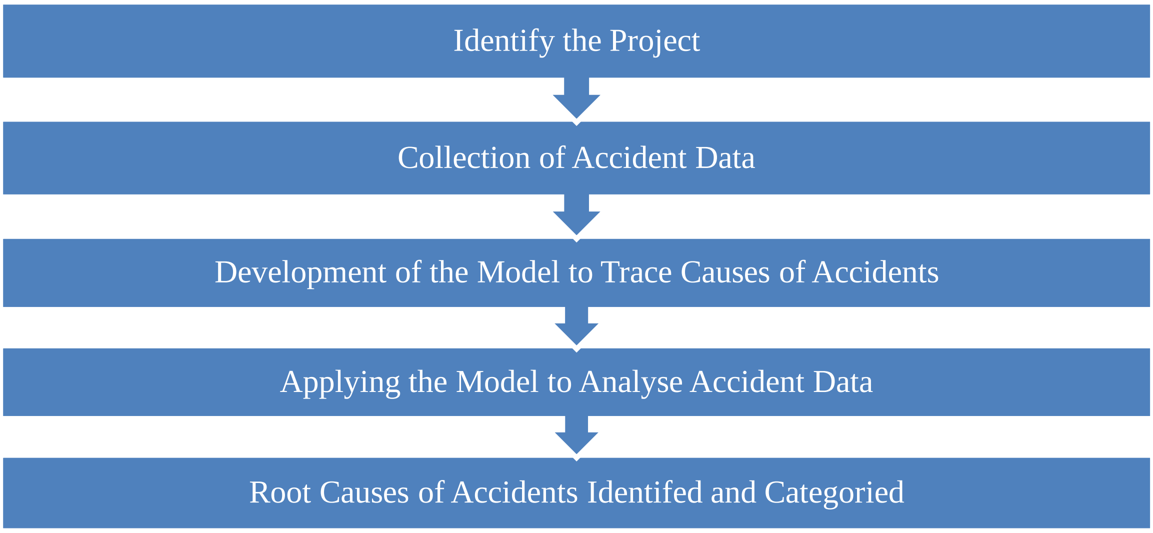

Figure 1: Process to Identify Root Causes of Accidents

4. NUMBER OF ACCIDENTS IN SELECTED PROJECT

The record maintained by the project HSE team shows that there was a total of 623 accidents from September 2011 to April 2016 as shown in Table 2. Property / equipment damage accidents were at the top with a total number of 580 accidents, followed by MTI (15), FAI (14), LTI (9) and AWI (5). The average numbers of workers on the project during this period (September 2011 to April 2016) were 2000.

Table 2: Summary of Different Types of Accidents (September 2011 to April 2016)

Year	Property / Equipment Damage	Alternate Work Injury (AWI)	First Aid Injury (FAI)	Loss Time Injury (LTI)	Medical Treatment Injury (MTI)	Total
2011	0	0	0	0	0	0
2012	7	1	1	0	2	11
2013	155	0	3	3	4	165
2014	164	2	0	5	5	176
2015	179	2	7	1	4	193
2016	75	0	3	0	0	78
Total	580	5	14	9	15	623

Considering the importance of inspection in ensuring proper health and safety at the workplace, the project HSE team was requested to provide a record of all internal and external inspections carried out during the project period. The ultimate purpose of the enforcing authorities is to ensure that duty holders manage and control risks effectively, thus preventing harm. The term ‘enforcement’ has a wide meaning and applies to all dealings between enforcing authorities and those on whom the law places duties (employers, the self-employed, employees and others). The purpose of enforcement is to:

- Ensure that duty holders take action to deal immediately with serious risks
- Promote and achieve sustained compliance with the law
- Ensure that duty holders who breach health and safety requirements, and directors or managers, who fail in their responsibilities, may be held to account.

The inspection record shows that there were a total of 2392 HSE inspections carried out during the project period (September 2011 to April 2016). The number of internal inspections conducted by the project HSE team consists of one HSE advisor and five HSE officers were 2376. The contractor head office HSE team conducted a total of 12 inspections. There were four inspections conducted by different government agencies out of which two were carried out by Civil Defence authority in 2013, One by Ministry of Manpower in 2014 and the last one was by Ministry of Environment and Climate Affairs in 2015. Table 3 shows the record of HSE internal and external inspections conducted from 2011 to 2016 on this particular project. There was no internal and external HSE inspection in 2011 and at the same time there was no accident recorded during this year (Table 2). On the other hand there was a total of 795 HSE inspections but in the same year the number of different accidents was 165 (Table 2). This however indicates the reduction of accidents on this particular project was not linked with the HSE inspection.

Table 3: Summary of Internal and External HSE Inspections on the Project (September 2011 to April 2016).

Year	Internal Inspections by Project HSE Team	External Inspections by Contractor Head office HSE Team	External Inspections by Government Authorities	Total
2011	0	0	0	0
2012	461	4	0	465
2013	791	2	2	795
2014	535	3	1	539
2015	406	3	1	410
2016	183	0	0	183
Total	2376	12	4	2392

5. RESULTS OF ANALYSIS AND DISCUSSION

The Health, Safety and Environment (HSE) policy of the construction organization define the procedure for incident reporting, which requires the workplace manager and HSE in-charge to determine whether a specific incident requires further investigation or not. The process of reporting an incident by the workplace manager and HSE in-charge include collection of necessary information to determine what happened, where and who was involved. To understand the causes of different accidents that occurred on the project, the project team was requested to provide the incident investigation reports for detailed analysis and study. A total of 44 different incident reports were provided by the HSE team of the project. These reports were initially assessed against the model developed for tracing the root causes of accidents. It was found that only 22 reports had sufficient information to be used for tracing the root causes. Thus the valid accidents data used are 50% of the total accidents reports received from HandS team of the project. Out of 22 reports, nine incident reports were classified as property / equipment damage, one as AWI (Alternate Work Injury), two FAI (First Aid Injury), five MTI (Medical Treatment Injury) and five as LTI (Loss Time Injury). A different set of questions were developed and applied to each incident. The model was validated by top management, including the HSE advisor, construction manager and project director of the construction organization. All the valid incidents reports were reviewed against these questions and a conclusion was made on the main or root causes of each incident.

After reviewing the incident reports against the set of questions shown in Table 4, eight incidents were matched to one root cause. The remaining incidents (14 incidents) were having more than one main root cause (Table 5). In 2012, seven incidents completed reports were provided by the project HSE team. Two incidents matched to one root cause of “worker” and another to “management”. The remaining four incidents in 2012 had more than one root cause.

From eight valid accident reports of 2013, one incident was matched to “worker” as a root cause while the remaining seven incidents had more than one root cause. In the year 2014, there were two valid accidents reports available. One incident had the root cause of “material / equipment” and one incident to the root cause of “worker”. The total valid accidents reports for the year 2015 were five out of which two incidents matched one root cause of “worker”, the remaining three incidents were having more than one cause as shown in Table 5.

Table 4: Model for Tracing Root Causes of Accidents

Equipment / Materials	Worker	Environment	Management
There was excessive noise from equipment or machines involved in the incident.	The worker involved in the incident was under fatigue / stress.	There was an ambient condition (wind, dust, rain, etc.) at the pace of the incident.	The incident was caused by hazardous method specified.
The machines, equipment or tools which were involved in the incident were difficult to operate.	The worker involved in the incident was having physical disability which was affecting performance.	There was excessive noise at the place of incident.	The incident was caused by lack of supervision / supervisor competence.
The machines, tools or equipment involved in the incident were malfunctioning or defective.	The incident was caused by the worker culpable act.	The incident was caused by poor lighting.	The incident was caused by the non - provision of correct safety equipment or clothing.
The materials / equipment involved in the incident was difficult to handle and maintain.	The incident was caused by worker skylarking or misconduct.	The incident was caused by terrain condition.	The incident was caused by inadequate training provided.
There was inadequate guarding or protection with the machines, tools or equipment involved in the incident.	The worker involved in the incident was having personal problems.	The incident was caused by temperatures.	The incident was caused by poor housekeeping standard.
The machine tools, or equipment involved in the incident is manual handling.	The worker involved in the incident was inexperienced in the task being performed.	The incident was caused by poor housekeeping.	The incident was caused by poorly maintained equipment.
	The incident caused by failure of worker to use safety clothing.	The incident was caused by building surface conditions (stairs, floors etc.)	The incident was caused by non-availability of suitable plant / equipment.
	The worker involved in the incident used a hazardous work method.	The incident was caused by storage / staking of material.	The incident was caused by inadequate or non-documented procedures.
	The worker involved in the incident was under the influence of alcohol or drugs.	The incident was caused by exposure or contact chemicals or other harmful material.	The incident was caused by insufficient / inadequate instruction or information.
	The incident caused by act or omission of another person or worker.	The incident was caused by exposure to infectious sickness / disease.	The incident was caused by production pressure from a supervisor or manager.
		The incident was caused by poor visibility.	
		The incident was caused by congested work area.	

Considering individual causes, for 5 incidents, "equipment / material" was one of the root causes. For 17 incidents, "worker" was one of the root causes of accidents. "Environment" was one of the root causes for 5 incidents; "management" was one of the root causes for 13 incidents; and equipment/material was one of the root causes for 6 accidents.

Table 5: Summary of Accident Classification and Root Causes of Accidents Investigated

Year	Accident Classification	Root Causes	Total
2012	Property/ Equipment Damage	Environment + Management	7
	AWI	Worker	
	Property/ Equipment Damage	Worker	
	FAI	Environment + Management	
	Property/ Equipment Damage	Worker + Management	
	Property/ Equipment Damage	Management	
	MTI	Equipment + Worker + Management	
2013	Property/ Equipment Damage	Worker + Environment	8
	Property/ Equipment Damage	Worker + Management	
	MTI	Equipment + Worker + Management	
	Property/ Equipment Damage	Worker + Environment + Management	
	LTI	Worker	
	MTI	Worker + Management	
	MTI	Worker + Management	
	Property/ Equipment Damage	Equipment / Material + Management	
2014	LTI	Equipment / Material	2
	LTI	Worker	
2015	Property/ Equipment Damage	Equipment / Material + Worker	5
	FAI	Worker	
	LTI	Worker	
	MTI	Equipment / Material + Worker + Environment + Management	
	LTI	Worker + Management	
Total			22

6. CONCLUSIONS

The proposed model for identifying the root causes could be a useful tool for construction organizations in Oman to know the root causes of accidents on their projects. This will help them to develop strategies towards reducing the number accidents and thus reduce the cost associated with accidents. By using this model, construction organizations will be able to pinpoint the key areas which cause most of the accidents. The proposed model identifies the main causes of accidents in construction that arise from equipment / materials, workers, environment, and management. Although the model is used only on a road construction project, it can be adopted and can be used on other construction projects. This investigation has revealed that a significant proportion of accidents (41%) arise from the "Worker". Furthermore, it is found that Management factor contribution is 31%, Equipment/Materials contribution is 14% and the Environment contribution is 12%. Different types of accidents are discussed and investigated in the research to identify their root causes. Understanding the main causes of construction accidents will aid construction organizations in directing their resources to high risk areas in order to improve their safety performance.

This work has described results of research where a model has been developed and applied to help identify the principal root causes of accidents on a major highway construction project in the Sultanate of Oman. The causes of accidents in construction will vary from project to project and from sector to sector in the construction industry. Exposure to the risk of construction hazards will also vary depending on whether the project is a new build or involves maintenance operations. The model developed in this study could be applied to accidents in other sectors including building, civil engineering, process plant construction, etc. It is essential that the model developed in this study is tested using accident data from other sectors in order to generalize the applicability of the model and the findings on the root causes of accidents in construction.

7. REFERENCES

Ali, A.S., Kamaruzzaman, S.N. and Sing, G.C. 2010. A Study on Causes of Accident and Prevention in Malaysian Construction Industry. *Journal of Design + Built*, 3(1), 95–104.

Abdelhamid, T., and Everett, J. 2000. Identifying root causes of construction accidents. *Journal of Construction Engineering and Management, ASCE*, 126(1), 52–60.

Anderson J. 1997.The problems with construction. The Safety and Health Practitioner, 29 May: pp. 29–30.

Booth, R. T., and Panopoulos, G. D. 2005."Economic aspects of safety in construction industry." In: *3rd Int. Conf. on Construction in the 21st Century (CITC-III): Advanced Engineering, Management and Technology*, Dept. of Construction Engineering and Management, Faculty of Civil Engineering of the National Technical Univ. of Athens, Athens, Greece.

BRT (The Business Roundtable), 1995. *Improving Construction Safety Performance Report A – 3*. The Business Roundtable, New York, NY, USA.

Choudhry R.M., Fang D.P. and Mohamed S. 2007. Developing a model of construction safety culture. *Journal of Management in Engineering*, ASCE, 23(4), 207–212.

Dubois A. and Gadde L. 2002. The construction industry as a loosely coupled system: implications for productivity and innovation. *Construction Management and Economics*, 20(7), 621–631.

Gibb A. Haslam R. Gyi D., Hide S. and Duff R. 2006. What Causes Accidents? Proceedings of the Institution of Civil Engineers – *Civil Engineering*, 159(6), 46-50.

Hamid A.R.A, Majid M.Z.A, and Bachan Singh 2008. Causes of Accidents at Construction Sites. *Malaysian Journal of Civil Engineering*, 20(2), 242–259.

Hinze, J. 1996.The distraction theory of accident causation. In: *International Conference on Implementation of Safety and Health on Constr. Sites, CIB Working Commission W99: Safety and Health on Construction Sites*, L. M. Alvez Diaz and R. J. Coble, eds., Balkema, Rotterdam, The Netherlands, 357–384.

Ikpe. E., Hammon, F. and Oloke D. 2012. Cost-Benefit Analysis for Accident Prevention in Construction Projects. *Journal of Construction Engineering and Management,* ASCE, 138(8), 991–998.

ILO, 2016, n.d,. [Online] Available from URL: http://www.ilo.org/safework/areasofwork/hazardous-work/WCMS_356576/lang--en/index.htm [Accessed 10/04/2016]

Kadefors A. 1995 Institutions in building projects: implications for excitability and change. *Scandinavian Journal of Management*, 11(4), 395–408.

Kadiri Z.O.; Nden T.; Avre G.K.; Oladipo T.O.; Edom A.; Samuel P.O.; and Ananso G.N. 2014. Causes and Effects of Accidents on Construction Sites (A Case Study of Some Selected Construction Firms in Abuja F.C.T Nigeria). *Journal of Mechanical and Civil Engineering*, 11(5), 66-72.

Lehtola, M.M., van der Molen, H.F., Lappalainen, J., Hoonakker, P.L., Hsiao, H., Haslam, R.A., Hale, A.R. and Verbeek, J.H., 2008. The effectiveness of interventions for preventing injuries in the construction industry: a systematic review. *American journal of preventive medicine*, 35(1), 77-85.

Lubega, H., Kiggundu, B.M. and Tindiwensi, D. 2000, "An Investigation into the Causes of Accidents in the Construction Industry in Uganda", In: *2nd International Conference on Construction in Developing Countries*, 15-17 November 2000, Botswana.

McClay, R.E. 1989. "*Toward a more universal model of loss incident causation*." Professional Safety, January, 15–20.

Mitropoulos P. Abdelhamid T.S. and Howell A.G. 2005. Systems Model of Construction Accident Causation. *Journal of Construction Engineering and Management*, 131(7), 816–825.

NCSI, 2015, Statistical Year Book, Issue 43. National Center for Statistics and Information, Muscat, Oman. [Online] Available from URL: https://www.ncsi.gov.om/Elibrary/Pages/LibraryContentDetails.aspx?ItemID=lffQDcPJGNjEE5Xix4WK2g%3d%3d [Accessed 21/09/2016].

Haslam R.A., Hide, S.A., Gibb A.G.F., Gyi D.E., Pavitt T., Atkinsonand S. and Duff A.R. 2005. Contributing Factors in Construction Accidents. *Applied Ergonomics*, 36(4), 401-415.

Suraji, A., Duff, A. R., and Peckitt, S. J. 2001. Development of causal model of construction accident causation. *Journal of Construction Engineering and Management*, ASCE, 127(4), 337–344.

Tang, S. L., Ying, K. C., Chan, W. Y., and Chan, Y. L. 2004. Impact of social safety investments social costs of construction accidents. *Construction Management and Economics*, 22(9), 937–946.

CHALLENGES IN MAINTAINING THE GREEN CERTIFICATION IN SRI LANKAN HOTEL SECTOR

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ABSTRACT

Green Certification towards the sustainable concept has become a remarkable area in the hotel industry. Sustainable concept is no more new for the hoteliers and sightseers seek greener of the accommodation prior to arrival. Green Certification is contributing towards creating an environment friendly hotel by integrating the sustainability concept. Most of the hoteliers perceive that the Green Certification is a marketing tool which increases the customer demand as well as profit. Also, it is kind of aggressive tools which can contribute to competitiveness in a successful manner. Some people are saying that the Green Certification is one of the energy saving mechanisms because it directly focuses towards energy saving aspects. Even though Green Certification is more important for the hotel sector, there may be some challenges when maintaining the Green certification. Therefore, investigating those challenges is an essential requirement for entire hotel sector towards the continuation of the Green certification. Hence, the aim of this study has been initiated to investigate the challenges in maintaining Green Certification in the hotel sector in Sri Lanka. A qualitative research approach was followed to investigate the challenges in maintaining Green Certification in Sri Lankan hotel sector and twelve individuals were interviewed from three cases to obtain data for the research. Semi-structured interviews were carried out as data collection method and the collected data were subjected to cross case analysis to investigate challenges. Eventually, the outcomes of this study demonstrated that there are several challenges in maintaining Green Certification and it was explored under five categories, namely technical, managerial, political and legal, environmental and biological, social and cultural.

Keywords: *Challenges; Green Certification; Hotel Industry.*

1. INTRODUCTION

The concept of “sustainable travel and tourism” is no longer new, it is now the norm and the adjacent few decades will challenge companies to differentiate themselves by looking elsewhere traditional environmental strategies in order to appeal to the rapidly growing market of socially and environmentally-conscious tourists (Miththapala *et al*., 2013). Chan (2013) stated that nowadays hotels have begun to implement a variety of environmental programs and they are considering about protection of environment, cost saving and environmentally friendly image. Author further highlighted that “Trip Advisor” conducted a survey in 2012 and revealed that 71% of the 700 American respondents would make eco-friendly travel choices in year ahead. It means most of the travellers in the world prefer green hotels. Gou (2016) stated that the people who are interested for green concept can apply for different standards and rating systems such as LEED (Leadership in Energy and Environmental Design), Hong Kong Building Environmental Assessment Method (previously

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known for BEAM, now BEAM Plus) for Interiors, Singapore Green Mark for Interiors, Australia Green Star for Interiors and so on.

Miththapala *et al*. (2013) stated that Sri Lankan tourism industry suffered seriously for 26 years because of war. Further according to the author, on the post war period since 2009, Sri Lanka tourism has rebounded strongly showing tremendous growth with arrivals exceeding the one million mark in 2012 and during the war tourists were not interested to visit Sri Lanka because of risk. The authors highlighted that due to the increased demand for hotel sector, they have to provide better tourism products and services to their guests' and better tourism products include natural beauty, diversity, traditions and culture. Around 177 four star hotels are located in Sri Lanka (Expedia Travel, 2016).Out of them, there are around 32 green hotels (Sri Lanka hotel, 2016).Currently, most of the hotels in Sri Lanka are using Green Globe Certification and there are more than 12 Green Globe certified higher star rated hotels in Sri Lanka (Green Globe, 2016). Maintaining of Green Certification is real challenge for hoteliers. Empirical study on investigation of challenges in maintaining of Green Certification in hotel sector, however is still lacking and mostly concentrated on challenges associated with implementation of green certification. Therefore, this research aimed to investigate the challenges in maintaining the Green Certification in hotel sector in Sri Lanka.

2. LITERATURE REVIEW

2.1. IMPORTANCE OF GREEN BUILDING CERTIFICATION FOR HOTEL INDUSTRY

According to Mensah (2006), hotels can be considered as the heart of the tourism industry and it is a major sector of economy in which maintaining, landscaping, cooking and disposal of waste, use of water and energy tend to affect the environment. According to Buultjens *et al*. (2016) most of the accommodation establishments in developed and developing countries follow national and international eco-certifications and standards because it is a proof that they are protecting environment. Inappropriate development of tourism industry degrades habitats and landscape, depletes natural resources, disturbs to the economic system and generates waste and pollution (Dowling, 2007). If tourism industry needs to be sustained and make profits in future, they have to mitigate negative environmental impacts (Clarke, 2010).

Green Building Certification program contributes to increase the demand of tourism industry and ultimately it will increase income to country because tourism industry has a huge contribution to the economy of a country (Plumb and Zamfir, 2009). Most of the certifications have developed around the world and these certifications act as tools for improving tourism practices and minimising the negative impact on environment, cultures and societies (Mehta, 2007). When further considering about benefits of Green Certification for the tourism organisations, it enhances attraction of more clients toward the hotel sector and provides better reputation and more popular because having of a Green Certification provides good choices for the consumers and increase public awareness and better quality service offer and also enhancing industry standards and lower regulations cost of environmental protection and ultimately it helps address to critical issues of world such as climate change and natural resource conservation (Winkler, 2011). Green certified hotel can guarantee that level of quality has been achieved and quality has linked with environmental and social management (Jhamb and Singh, 2016). The next section discuss about the applicability of green concept in Sri Lankan hotel industry.

2.2. GREEN CONCEPT IN SRI LANKAN HOTEL INDUSTRY

Hotel industry contributes to Sri Lankan economy with more income and after the 30-year war, hotel industry is rapidly developing and foreigners coming to visit Sri Lanka with increasing rates day by day (Ramgade and Walvekar, 2016). According to Ramgade and Walvekar (2016), majority of tourists are from Europe who arrive on package trips to visit beach areas and Sri Lankan hoteliers expect to offer ecotourism to attract more visitors and increase the number of visitors up to 1 million per year and to achieve this goal, most establishments are trying to use their own unique attractions that are available in Sri Lanka. The authors further emphasised their most recent campaign slogan is "Beyond the beach: nature, culture and adventure". According to Kristanti and Jokom (2016), most of hoteliers would like for 15-20% of their visitors to be environmentally interested in ecotourism because it gains higher revenue for the country. Furthermore, Kandalama and Tree of Life are two large luxury hotels that have Green Certification which meet environmental standards.

Sri Lankan hotel industry widely uses Green Globe and LEED certifications (Arachchi, Yajid and Khatibi, 2015). Further to them, LEED certification is not renewable and Green globe certification should be renewed every year. Since this study is aimed to investigate challenges in maintaining the Green Certification in Sri Lankan hotel sector, only the green globe certified hotels were selected as it is renewed yearly. The next section discusses the research methods adopted in this study.

3. RESEARCH METHODOLOGY

The study was carried out through qualitative research approach. Identification of 'Unit of analysis' is very important to any research design and it is linked with the way the research problem is created (Swanborn, 2010). In this research, case study boundary is Green certified hotels in Sri Lanka and unit of analysis was Green Globe Certified hotels in Sri Lanka. When the study area is too broad in a qualitative research, ideal number of cases is one or two and utmost four (Taylor, 2000). Therefore, this research was limited to three cases where the empirical study focused on four to five star Green Globe Certified hotels. Table 1 gives a brief description about the selected three cases. The researcher selected semi-structured interviews as data collection techniques for the selected case studies. Cross case analysis was selected as analysing technique and NVivo 11 as qualitative data analysis package.

Table 1: Case Study Description

	Case A	Case B	Case C
Recognition	5 Star	4 Star	4 Star
No of Rooms	200	346	150
Green Awards Received	LEED, ISO 14001	Energy saving certification, Greening awards 2014 from the hotels association of Sri Lanka	ISO 14001
Green Globe Certified Year	2015	2014	2013
Selected Interviewees	Chief Engineer Assistant Engineer Garden Supervisor Maintenance Supervisor	Chief Engineer Assistant Engineer Garden Supervisor Maintenance Supervisor	Maintenance Engineer Assistant Engineer Garden Supervisor Maintenance Supervisor

4. RESEARCH FINDINGS AND ANALYSIS

The cross-case analysis is based on the challenges in maintaining the Green Certification in green certified hotels. Challenges were identified in depth under five main categories namely, such as Technical, Managerial, Political and legal, Environment and biological, Social and cultural (refer Figure 1). Those will be the basis for following discussion.

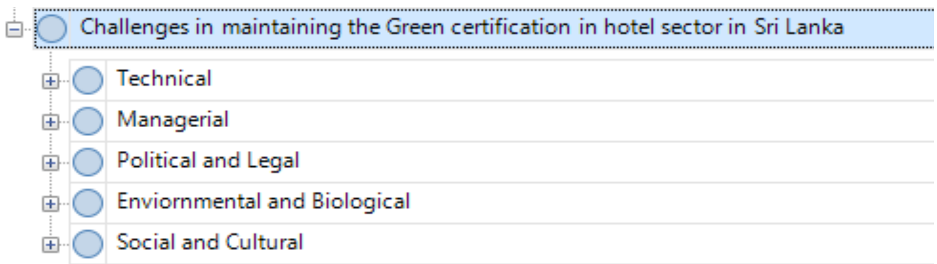

Figure 1: Coding Structure for Challenges in Maintaining the Green Certification

4.1. Technical Related Challenges

All challenges related to technical category are discussed under this Section. Design means how building structure and its elements have built up initially. When maintaining the building after the construction, it can create various difficulties due to a design error. There can be difficulties with design errors and it is leading to high maintenance cost. As an example, Chief Engineer of Case B held that "*direct sunlight gets into the room through windows and it should be double glazing. If not sunlight comes into the room and heat the room which leads to increase the energy cost of the building"*. Similarly, Assistant Engineer of Case B stated "*there are few design errors in the building. Because of those errors, some of the rooms have been exposed to direct sunlight in many times throughout the day. Therefore, heating load of the building is increasing rapidly and it causes to increase energy consumption of the hotel badly"*. Building orientation is very important when considering energy savings in the building. Because of some of the area in the building can expose to direct sunlight due to a design error. Then the building is heated and it requires more air conditioning and ventilation to the building which will ultimately, increase energy cost.

Most of the beach side hotels require regular painting due to sea wind. As an example, Chief Engineer of Case A mentioned that since building facade is discoloured due to sea wind, regular painting is required which leads to high maintenance cost of the building. Another thing is regular painting will lead to environmental pollution as most of paints contains chemicals which may have harmful emissions. According to Maintenance Supervisor of Case C, it is better to find initiatives for building painting because some paints are not environmental friendly and it can harm to the environment when doing regular painting. This challenge was reported by several individuals. Most of the Green Certifications are generally prohibit the use of harmful substances such as paints, pesticides, and swimming pool disinfectants. However, use of environmental friendly paints is very expensive as per the expertise. Hence, this has become a significant challenge for most of the hoteliers, especially in beach side located hotels in Sri Lanka, due to regular painting.

4.2. Managerial Related Challenges

There were several managerial defects and those challenges gathered under this category and it was divided into four parts, namely Project management, Maintenance management, Resources management and Economical and Financial.

- **Project management**

Most of the hotels have been involved in several kinds of projects such as modifications, replacement, re-building, gardening projects etc. Many difficulties may arise when handling those projects. Research findings revealed three main challenges under this category such as difficulty in selecting environment friendly raw material (1); difficulty in selecting the right material for projects (2); difficulty in selecting appropriate suppliers (3).

Green certified hotels should more concern about environmental friendly practices when they are handling projects within the premises. Delivering of any harmful material within the premises is restricted as per the requirements mentioned under the Green Certification (1). However, use of 100% of environment friendly material is not practical as per the interviewees due to high cost and availability issues of the same. For an example, Chief engineer of Case A stated "*Normally we do concern about environmental friendly raw materials. As an example, we do not use asbestos for any kind of project. But, going for environmentally friendly raw materials are very expensive and not much practical all the time. Sometimes we may have to import from other countries which would be more expensive and we do not have enough budget"*. Generally yearly budget is defined at the beginning of the year. Consequently they have to manage all projects within the budget limit and they cannot exceed the budget going for expensive environment friendly material. Accordingly, experts viewed this as challenge for hoteliers where they confront difficulty in finding environmentally friendly material in every time because of availability problem as well as high cost.

There are so many local products in the market with low quality and hoteliers have been facing difficulties when selecting right material for projects. Since there are so many alternative materials in the market, selection of the right material among that is a little bit difficult due to fraud suppliers as per the experts (2). As an example, some of the LED bulbs are not reducing energy cost because of low quality. Chief Engineer of Case B quoted "*We should check whether we are getting the right product or not. Sometimes a salesman doesn't know exactly about the products. After installation, it might be failed due to wrong products*". Respondent further stated that there are no any standards for local market and there are so many products with low quality. When using improper material, the entire project will be failed within small period. Therefore, selection of right product from the local market is difficult when implement the projects. The third most common challenge under the category of Project Management is difficulty in selecting appropriate suppliers (3). According to the interviewees, currently there is no proper procedure to select right material suppliers. Research findings further revealed that many of material suppliers are not registered under legal body in Sri Lanka.

- **Resource management**

There are several resources in a hotel such as assets, human resources, water and electricity etc. The difficulty in minimising of high water consumption, especially during dry season and high turnover of human resources were identified as the most common challenges in the category of 'Resource Management'.

Sri Lanka is a tropical country which is having a dry season in several months throughout the year. Therefore, high water consumption in the dry season is one of the challenges faced by Sri Lankan Hotel sector. The reason for that is there are a few months in the year which is getting high sunlight and environment become dry. During that period, water consumption is high because they have to maintain the garden and plants as in other months and if not plants can be dying due to a dry environment. Also, most of the Green Certified hotels concern about water efficiency and they are trying to apply several kinds of mechanism to reduce the water consumption. Assistant Engineer of Case C stated that water flow rates of taps in guest room are high. Therefore, they were supposed to apply sensor tap for the guest room. However, sensor taps were could not install for rooms because hot water and cool water cannot be mixed through sensors. As a result of that guest complaint will arise. Customers are expecting luxury services from hotel management and some of them do not care about water saving or efficiency. Only thing is they need their requirement as they wish. Therefore, hoteliers currently face difficulty in going for saving while balancing customer satisfaction.

As mentioned in above high turnover of human resources is another is another challenge identified during the study. Most of the people who are working in the hotels are in busy schedule because of high workload. Sometimes they have to work until midnight. Mostly turnover of human resource is happened due to dissatisfaction of employees. Maintenance Supervisor of Case A highlighted that their guest is changing day by day and there are only few regular guests. Therefore, workload of workers is high which could be a reason for them to leave the job. Chief Engineer of Case B explained that and they have to recruit new employees frequently due to prevailing situation and most of them are non-experiencing workers with regard to sustainability. Hence, conducting of same training programmes continuously for newcomers is costly.

- **Economic and Financial**

The budget is very important and cost is the highest concern factor in any organisation. Implementation of sustainable projects is costly and payback period is also comparatively high. As an example, Assistant Engineer of Case A stated that "*Engineering department has suggested many projects such as solar systems and garden lighting system. The challenge is to get approval from top management. Since the capital cost of the projects and payback period is high, approval can be delayed or rejected*". Most of the organisations concern about the cost and they do not like to go for mega projects even it has more payback. Chief Engineer of Case B respondent stated "Top m*anagement is not saying to do a project with high cost. They are always saying reduce the cost. Most of the green project is very expensive and payback periodic is high. They do expect maximum payback period is one or two years*". He further stated that if ROI (Return on Investment) of the project is exceeds the two years, management of the hotel is do not like to give approval for the particular project. Accordingly, some of sustainability related projects are challenging to the hoteliers as per the experts.

4.3. POLITICAL AND LEGAL RELATED CHALLENGES

Various policies or standards which are implemented by government can cause some difficulties when maintaining the green certification. Interviewees mentioned that most of the Green Certified hotels should maintain test reports in proper way, such as generator emissions report, boiler emissions report, kitchen emissions report and all other discharging parameters and those reports should be submitted to the regulated body namely Central Environment Authority (CEA), Municipal Council in periodically. Since some of these tests are taken place in daily, allocation of separate person for respective job is required. However, allocating a separate person to do test daily is costly and difficulty with the limited staff available. Further, Chief Engineer of Case B stated "*If the boiler is not maintained properly, harmful emissions will discharge to the environment.*

It will discharge carbon monoxide to the environment. We have to control this situation. Therefore, we should maintain properly and emissions should test once in year. It is called flow gas analysis. We should submit all test reports to the CEA". According to Assistant Engineer of Case B, liquid waste and solid waste are generally handover to municipal council and liquid waste parameters should be tested daily. Further to him, internal auditors are very strict on this and they do check all testing detail properly as most of the Green Certified hotels cannot discharge liquid waste without any treatment. Further, Maintenance Supervisor of Case B held "*Generator emits some kind of gases and we should test those gases and discharge*". Maintenance Engineer of Case C also said that generator emits harmful gas, but they cannot discharge to the environment as it is. It is therefore testing needs to be done to reduce the impact of that gas by using some chemicals. Accordingly, a proper program to maintain all test reports is required which sometimes costly and time consuming. Since this challenge reported by many individuals, it can be considered as a common challenge for the entire hotel sector in Sri Lanka.

The water consumption report should be submitted in periodically. When there is an increment of regular water consumption by month, the reason for increment should be presented to auditors. Even though the guest is not concerning water saving, hotelier should control water consumption. Maintenance Engineer of Case C held that they should prepare a monthly sustainability report which includes ground water consumption and city water consumption. Further, he explained that city water and ground water should be reduced according to the global requirement when going sustainability concept. Because people are taking ground water from several sources and with the time being the entire ground water level of the earth will be reduced.

4.4. ENVIRONMENTAL AND BIOLOGICAL RELATED CHALLENGES

Challenges identified under this category are discussed under two headings; namely, Environmental and Biological. Environmental climate has been changed due to environmental pollution and it creates many challenges when maintaining the green certification. Condensation is one of the challenges which was highlighted by Assistant Engineer of Case A. He emphasised that "*When guests open balcony door or some amount of air conditioning will reduce and fresh air comes into the room. Then the wall is wet and emits a bad smell. And also due to condensation floor will be slippery and guest may get injured*". This situation leads to create an energy loss as per the experts. With this context, installation of dehumidifiers is required in all guest rooms to mitigate the consequences. It is an additional cost to their organisation. Garden Supervisor and Maintenance Supervisor of Case A also expressed similar ideas as mentioned by the Chief Engineer of Case A. Another thing is customer satisfaction is decreasing due to the cold surface inside of the room. Garden Supervisor of Case B indicated that "*Guest rooms are getting wet due to humidity and it's a design error*". According to above respondent's opinions, it is realised that this is a common challenge for most of the hotels in industry when maintaining the green certification.

During the study, it was noted that plywood furniture have been used in most of the hotels which are located in coastal area with the purpose of enhancing aesthetic appearance to the hotel and it was a decision, taken at the design stage. However, interviewees mentioned that such furniture emits a bad smell due to sea wind. Assistant Engineer of Case A stated that since case A is a beach side hotel, always they are getting sea wind and it is effect to the indoor furniture of the hotel. They have used plywood furniture in some area which emits bad smell due to wetness with salt mixed air. The guest does not like that bad smell and they are complaining. As per the Green Certification, customer is the central focus of the tourism experience and customer satisfaction should be focused because they are the people who generate the revenue for the hotel. Replacing of plywood furniture with hardwood furniture is challenging at the moment as per the experts as well as it is very expensive when replacing existing furniture.

Biological growth, such as algae, fungi may create difficulties when maintaining green certification. Central corrosion is kind of discoloration issue in internal wall because of the sea breeze. Most of the inside area of the hotel has central corroded and it has taken light yellow colour with small spots on the wall. Chief Engineer of Case A quoted "*One of the challenges is central corrosion and growth of fungus. Central corrosion and growth of fungus are occurring due to wetness on the inside in the hotel. Because of we have planted some plants inside the building*". Chief Engineer of Case B quoted "*we cannot off the A/C units because fungus is growing after shut off the A/C machine. The reason is a humidity of inside the room*". Indoor environment has to be properly managed because central corrosion and fungus directly effect to the customer satisfaction because of they are the people who is highly concerned about the beautiful environment with a better appearance. According to the Green Certification, erosion and other air contaminant should be reduced and it should not damage to the ecosystem and human of the hotel. Not only that but also this situation leads to generate many guest complaints within the premises. With the existing environmental condition, it is a real challenge for hotel management to enhance customer satisfaction as per the research findings.

4.5. SOCIAL AND CULTURAL RELATED CHALLENGES

Social and cultural related challenges are discussed under this section. Many parties are involved in hotel operations such as outside contractors, suppliers etc., in addition to the hotel staff and guests. Handling those parties is not an easy task. Poor human attitudes and bad behaviours were one of the leading issues identified and it has been created many issues. As an example, Chief Engineer of Case A stated that although they have taken many initiatives for reducing energy, cost etc. occupants are not practicing them. Guests are not concerning about energy consumption and they do not care of operating lights and all when they leave from the room. Assistant Engineer of Case A held "*Some of the guests leave the room without switching off lighting and all. Although we wanted to change this situation by changing their attitudes, it has become a real challenge with regard to same*". Maintenance Supervisor of Case C highlighted "*When using energy and water, customers are informed about how to save energy and water in their rooms. But some customer's attitudes cannot change by us*". Further, he explained that not only guest, but also outside people such as contractors do not care about the energy cost of the hotel.

Lack of awareness of users also can cause some difficulties. As an example, Chief Engineer of Case A mentioned that most of the outside workers do not have much knowledge about sustainability concept and they do their activities which can cause to pollute the hotel environment. They are putting debris of renovation projects everywhere and they do not segregate those wastes. Therefore, as engineering division, training and awareness program need to be conducted for outside workers before entering the workplace. And also work permit is issued for every outside party. Sometimes it is time consuming with their busy schedules. Assistant Engineer of Case A mentioned that "*When doing small projects, many of outside people come to this hotel. Main challenge is lack of awareness of these people and always we should give instructions to them. Most of the contractors are not aware about waste segregation, safety and all and most considerable fact is that they do not really care about it*". Therefore, many waste items are generated due to the prevailing situation and in-house cleaning staff has to dispose properly without harm to the environment. Maintenance Supervisor of Case A also expressed that some of outside contractors are not following rules and regulations of the hotel. Similarly, Assistant Engineer of Case C mentioned that "*When we are doing project we have to train the contractors and our staff. One of the challenges which we identified is some of labours are non-experiential and non-educated. Therefore, educating and training of them is a real challenge for us*". When considering above all opinions it seems that dealing with un-educated outside contractors is a challenge to hoteliers. The next section draws conclusions for the discussion.

5. SUMMARY AND WAY FORWARD

Green Certification deliberates as a marketing tool for hotel industry which assistances to upsurge guest demand with the attraction. Even though having such paybacks through Green certification, maintainability of a Green Certification is not an easy task for hoteliers since have to comply with such criteria of Green certification. Aim of the study was investigate challenges in maintaining Green Certification in hotel sector in Sri Lanka. Aim was succeeded through investigating challenges faced by hotel sector in Sri Lanka. These challenges were mainly identified under on main five categories as Technical, Managerial, Political and Legal, Environmental and Biological, Social and Cultural. Further research proposed related this work could be developing strategies to mitigate challenges identified in this study.

6. REFERENCES

Arachchi, R.S.S.W., Yajid, M.S. and Khatibi, A., 2015. Ecotourism Practices in Sri Lankan Eco Resorts: A Supplier Perspective Analysis. *JTHM*, *3*(5), 155-171

Buultjens, J., Ratnayke, I., and Gnanapala, A., 2016. Whale watching in Sri Lanka: Perceptions of sustainability. *Tourism Management Perspectives*, *18*, 125-133.

Chan, S.W. E., 2013. Gap analysis of green hotel marketing. *International Journal of Contemporary Hospitality Management*, *25*(7), 1017-1048.

Clarke, A., 2010. Cultural Tourism and Sustainable Local Development. *Tourism Management*, *31*(5), 695-696.

Dowling, R. K., 2007. Book Review: Critical Issues in Ecotourism: Understanding a Complex Tourism Phenomenon, Edited by James Higham. *International Journal of Tourism Policy*, *1*(3), 286. doi:10.1504/ijtp.2007.017044

Expedia Travel: Vacations, Cheap Flights, Airline Tickets and Airfares, 2016. [Online]. Available from http://www.expedia.com [Accessed 05 November 2016].

Gou, Z., 2016. Green building for office interiors: challenges and opportunities. *Facilities*, *34*(11/12), 614-629.

Green Globe | Green Globe Certification - Certified Sustainability, 2016. [Online]. Available from http://greenglobe.com [Accessed 18 November 2016].

Jhamb, R., and Singh, G., 2016. *Corporate Social Responsibility in Hotel Industry*: *Corporate Social Responsibility in the Hospitality and Tourism Industry,* IGI Global: USA

Kristanti, M., and Jokom, R., 2016. The Influence of Eco-friendly Attitudes on Tourists' Intention Toward Green Hotels. *Balancing Development and Sustainability in Tourism Destinations*, 21-29.

Mehta, H., 2007.Green globe: a global environmental certification programme for travel and tourism. *Quality assurance and certification in ecotourism*. CAB International: UK

Mensah, I., 2006. Environmental management practices among hotels in the greater Accra region. *International Journal of Hospitality Management*, *25*(3), 414-431.

Miththapala, S., (Chandi) Jayawardena, C., and Mudadeniya, D., 2013. Responding to trends. *WW Hospitality Tourism Themes*, *5*(5), 442-455.

Plumb, I., and Zamfir, A.,2009. A comparative analysis of green certificates markets in the European Union. *Management of Env Quality*, *20*(6), 684-695.

Ramgade, A., and Walvekar, S., 2016. Sri Lanka a Favourite Tourist Destination Issues and Challenges Faced by the Srilankan Tourism Industry. *ATITHYA: A Journal of Hospitality*, *2*(1).

Sri Lanka Hotels | Heritance Hotels and Resorts Sri Lanka Official Site| Luxury Hotels, 2016. [Online]. Available from http://www.heritancehotels.com [Accessed 06 November 2016].

Swanborn, P. G., 2010. *Case study research: What, why and how?* SAGE: Los Angeles

Taylor, G. R., 2000. *Integrating quantitative and qualitative methods in research*. Lanham, MD: University Press of America.

Winkler, G., 2011. *Green facilities: Industrial and commercial LEED certification*. McGraw-Hill: New York.

CHALLENGES OF TRANSCENDING BIM INFORMATION FROM DESIGN PHASE TO REAL TIME ON-SITE CONSTRUCTION PHASE

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ABSTRACT

Building Information Modelling (BIM) is a revolutionary paradigm which espouses modernization and innovativeness to the conventional Architecture, Engineering, Construction and Operations (AECO) industry. Successful BIM model is enriched with information which was congregated during design phase and such information should be circulated throughout the project life cycle without disturbing its originality. Nevertheless, when the complete BIM information is transferred to the site office, the on-site personnel are not absorbing the real essence of effective BIM information for on-site construction activities. Improvements in Mobile Computing Technology (MCT) have succeeded in linking this communication gap through forms of electronic pocketbooks, personnel laptops and Personal Digital Assistants (PDA). Even though, there is a greater push from technology, site personnel are not willing to accept it and they still prefer the traditional procedure. This discloses that site personnel are not prepared to practice such technologies due to their nature of Resistance to Change (RTC). Subsequently, the aim of the research is to identify the challenges of transcending BIM information from design phase to real time on-site construction phase.

To accomplish the aim, a qualitative research approach was followed, steering semi-structured interviews. The gathered information was analysed rigorously through computer based content analysis. This topical study manifest that, all the recognized resisting factors extensively challenge the transcending of BIM information to the on-site construction phase. Hence, the research has successfully identified the challenges which barricade the transcending of BIM information to real time on-site construction phase.

Keywords: *Building Information Modelling (BIM); Mobile Computing Technology (MCT); On-site Construction; Resistance to Change (RTC).*

1. INTRODUCTION

Building Information Modelling (BIM) is a modern technology which replaces the traditional methods and adopts modernization to conventional Architecture, Engineering, Construction and Operations (AECO) projects. BIM enabled construction projects are enriched with information which should be circulated throughout the project life cycle efficiently and effectively. The project information collected in the model during design phase should be communicated to the people in the site. However, there is a gap in transferring the BIM information to the site personnel in construction projects. Thus, the research pursed to identify probable challenges that barricade the transcending of BIM information to real time on- site construction.

The paper comprehends the preliminary findings of the literature synthesis on how work force responds to a new technology through an extended model of Technology Acceptance Model (TAM) and Resistance to Change (RTC). Then, it expounds the traditional method and modern methods of communication available in a BIM enabled on-site construction. Finally, the research manifests the research findings which were collected and analysed through semi-structured interviews and computer aided content analysis respectively.

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2. BACKGROUND

Construction industry is reflected to be an information concentrated environment where information should be appropriately communicated from design phase to construction phase (Chen and Kamara, 2008). Consequently, Raj and Arokiaprakash (2016) explained that communication is the most vital aspect of success which is essential for optimum coordination in a Temporary Multi Organization (TMO). Even if, the construction communication plays an important role in project success, construction stakeholders across disciplines still rest on the traditional paper based communication methods where the collaborative effort is mostly based on the exchange in two dimensional (2D) drawings and documents (Goh *et al.*, 2014). However, Tessema (2008) highlighted that, traditional method of construction communication is considered to be an imperfect method of coordination which results in project delays and redundant tasks.

Favourably, Goh *et al.* (2014) underlined that, BIM is the best solution for problems in traditional communication method. As per Eastman *et al.* (2011), BIM can be used to reduce the number of flaws and incompatibilities of modern construction projects by providing more accurate and contemporary information to its stakeholders. Although, BIM is extensively used in the design stage, a relatively smaller number of site personnel use it in the construction phase as they are still reigned by paper based drawings (Davies and Harty, 2013). Accordingly, the site personnel in a BIM based construction project are not being able to collect all the BIM information required at the building site, even though the complete BIM information is transferred to the site office (Kerosuo *et al.*, 2015).

As a solution to the aforementioned problem, various forms of Personal Digital Assistants (PDA) in Mobile Computing Technology (MCT) have been introduced to BIM enabled construction sites which have the potential to solve these issues and allow site personnel to use BIM information at construction sites (Kimoto *et al.*, 2005). Despite the fact that, there is a greater push from technology to fill the information gap within BIM enabled construction site, most of the site personnel are not willing to accept it and still prefer the traditional paper drawings (Van Berlo and Natrop, 2015). Therefore, Kerosuo *et al.* (2015) emphasized that site personnel are not prepared to practice BIM themselves at the construction sites due to their RTC. Accordingly, Chi *et al.* (2013) stressed that, studies have not been carried out to explore the challenges related to transcending of BIM information to the real time on site construction phase. Thus, it is essential to investigate these resisting factors which barricade the acceptance of aforementioned new technology, in order to mitigate or eradicate them for the better implementation of BIM.

3. TECHNOLOGY ACCEPTANCE MODEL (TAM)

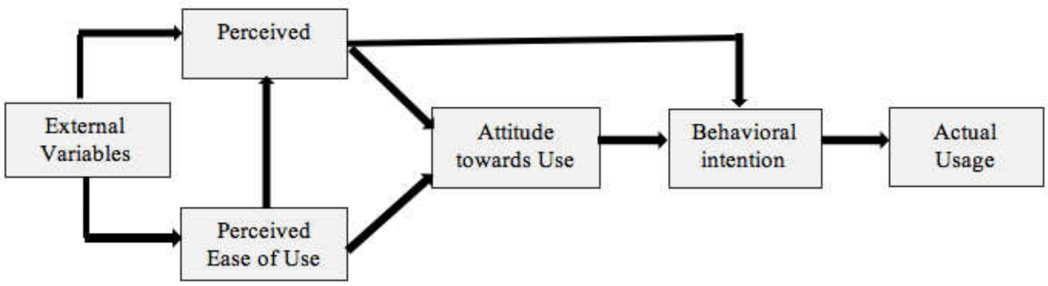

Figure 1: Technology Acceptance Model
(Source: Davis et al., 1989)

In 1989, Davis introduced the TAM which was specifically developed to investigate the effect of new technologies on its user's perception. Figure 1 illustrates the original TAM. In this model, 'Perceived Usefulness' (PU) and 'Perceived Ease of Use' (PEOU) are the primary constructs which are relevant to the acceptance of technology by an end user. According to the definitions given by Davis (1989), PEOU is "the degree to which a person believes that using a particular technology would be free from effort" (p. 320) and PU is "the degree to which a person believes that using a particular system would enhance his or her job performance" (p.320). In addition, Attitude Toward Use (ATU) is described as the assessment of the desirability of employing a novel system and Behavioural Intention to Use (BIU) is referred to a measure of the strength of one's likelihood to employ the particular system (Fishbein and Ajzen, 1975). The actual system usage is considered to be the dependent variable of TAM which will be determined by BIU. BIU is influenced by ATU which is subjected to the behaviour of two primary determinants; PU and PEOU. Finally, both these constructs are theorized to be directly influenced by external variables.

4. RESISTANCE TO CHANGE (RTC)

According to Manzoni and Angehrn (1997), RTC is one trait of individual behaviour which critically influences for the technology acceptance within an organization. Thus, the resistance is a negative personal attitude which arises as a response to a change and effort to stop the change before or after it implement. Table 1 shows the causes for RTC which prevent an individual from accepting a new technology.

Table 1: Causes for RTC

Key	Resistance factor	Content	Ref. Code
		Individual Factors	
R1	Interpersonal relationship altered	People are having fear that new technology might disrupt their existing organizational relationships.	5
R2	Loss of self esteem	If the new technology transformed their work and its status damaging their self-esteem, they will resist to change.	9
R3	Loss of power	If the new technology alter the working process result in decrease in their existing powers, users will resist to such change.	8
R4	Loss in job satisfaction	Sometimes technological change can simplify a person’s job and this may lead to less job satisfaction for them.	5
R5	Lack of knowledge and competencies	If people aware that they lack knowledge, skills and competencies required to adopt a new technology, they try to resist the implementation.	5, 7
R6	Lack of trust	People resist to change as they lack trust and are hesitant whether it can be used to fulfil their job activities.	2, 5
R7	Negative prior experience	If people have a prior negative experience with adopting new technologies, they will try to resist the new technology.	1
R8	Fear of failure	Some people are in fear of failing the technology adaptation from their birth which is known as technophobic effect. These people resist new technologies than others.	9
R9	Loosing comfort zone	People are considered as habitual creatures who do not like to escape from their accustomed things. When technology change violates their comfort zones, they try to resist it.	1, 4
		Organizational Factors	
R10	Change in work load	If, the new technology increases existing workload, such system may be rejected by new users.	1, 4
R11	Fear of redundancy/ treat to job status/ security	According to literature, people are highly afraid of adopting new technologies because they are uncertain on losing their existing position within the working environment.	5, 7
R12	Lack of training	If adequate training is not provided to workers, they become uncomfortable with technology usage and try to resist.	6, 7
R13	Lack of organizational support.	When top management does not support the workers to use the system by facilitating necessary resources and materials, they tend to resist.	7
R14	Lack of user participation	If users are not properly involved (views are not considered), they may feel that they are unimportant and try to resist.	6
R15	Lack of communication	If technology change has not properly addressed to the workers, they try to resist the new system.	4
R16	Misunderstanding	When users are not aware of the benefits of the technology, they try to resist for it.	4
R17	Change in decision making process	When implementing a new system, it will change the existing decision making process of the company which will lead to resistance again.	8

Sources: (Adapted from 1- Bagranoff *et al*., 2002; 2- Biranvand *et al*., 2015; 3- Bordia *et al*., 2004; 4- Egan and Fjermestad, 2005; 5- Landles, 1987; 6- Malato and Kim, 2004; 7- Pajo and Wallace, 200; 8- Smith and McKeen, 1992; 9 - Timmons, 2003)

5. INCORPORATING RTC IN TO TAM

According to Cheng e*t al.* (2013), in technology acceptance theory, the factors that encourage to adopt new technologies are PU and PEOU, whereas the inhibitor that obstructs the acceptance is end user RTC. Thus, original TAM can be criticized as it only considers the enablers that have influence on user's attitude but ignores the negativity of resistance to change.

However, in order to barricade this censure, many researchers have attempted to develop extension models of TAM which exhibit the influence of RTC more effectively. Nonetheless, RTC cannot incorporated directly into TAM because there is a discrepancy, as TAM shows the positive side where as RTC shows the negative side of users' nature of acceptance. Therefore, in order to incorporate RTC into TAM the original TAM model has been converted into its negative side without damaging to its original essence of theory.

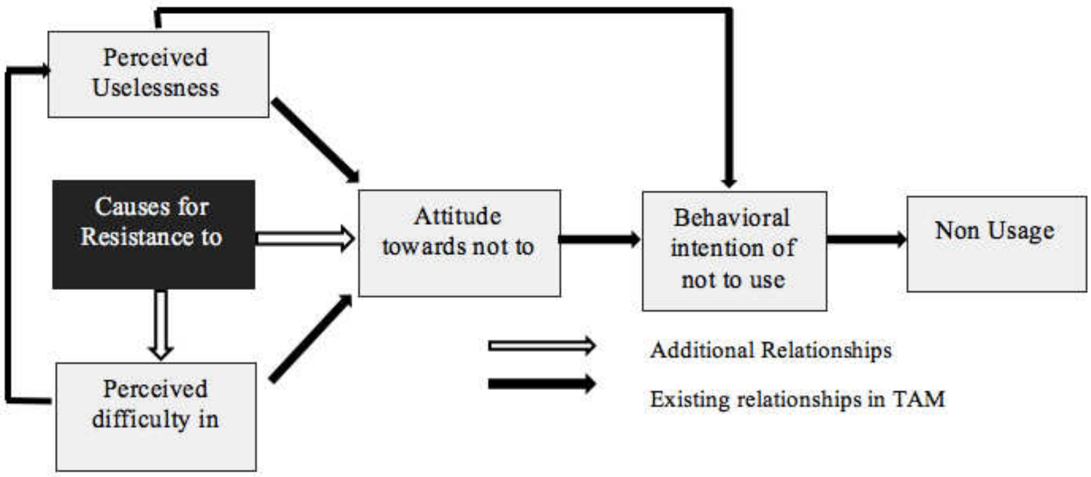

Figure 2: The Extended TAM Incorporating RTC
(Source: Biranvand *et al*., 2015; Nov and Ye, 2008)

As per Oreg (2003), people who sense more causes for RTC would discover it challenging to work successfully when a new technology is being introduced. Therefore, such users will require more effort in accepting a new technology as they have to overwhelm undesirable mental responses generated due to the new technology. Thus, Nov and Ye (2008) proved that, there is a positive relationship between RTC and perceived difficulty in use. Ultimately, such perception will inspire the user to reject the technology.

Moreover, according Biranvand *et al*. (2015), RTC has tremendous negative effect on users' attitude towards using a new technology. This emphasized that, when users' RTC is high, admittedly their attitude towards using the new technology will become low. Thus, from the above two additional relationships it is clear that RTC is an equally important component that should be incorporated in to the TAM.

6. TRADITIONAL METHOD OF INFORMATION USAGE IN BIM ENABLED ONSITE CONSTRUCTION

The traditional method of information management is still prevailing in BIM based construction sites. As per many researchers like Davis and Harty (2013) and Kimoto *et al*. (2005), traditional information management is still dominant in the forms of drawings, design information and other paper based material. Further, Mohamed and Stewart (2003) emphasized that, face to face meetings and exchange in documents like specification, technical drawings and site instructions also can be seen as methods of traditional construction communication. Accordingly, Son *et al.* (2012) confirmed that, the existing information management is mostly labour intensive and manual intrusion.

When discovering the process of existing information management, Chen and Kamara (2008) discovered that, a project manager is the main source of information in a construction project and from him information is transferred to the subsequent professionals at site such as site engineers, supervisors and other professionals. The final destination of this link is the operational level worker at the site. Thus, it is implied that the existing information process is kind of a hierarchical process where each professional has established their own power, self-esteem and self-respect.

The construction industry has suffered from many difficulties due to traditional modes of on-site communication. According to the research carried out by Hewage and Ruwapura (2006), it was found that over 40% site personal have criticized about the lack of communication at site level due to traditional method of communication. In addition, Mohamed and Stewart (2003) identified that, only 20% of the design information is transmitted to the operational level worker in a construction site. Accordingly, Hewage and Ruwapura (2006) found that, most of the on-site construction problems occur due to this unsatisfactory communication and exchange of information within the site premises. After analysing all these facts, it can be determined that the traditional method of communication is a devastating method for the success of a BIM enabled construction project.

7. MODERN METHODS AVAILABLE TO USE BIM AT SITE LEVEL

According to the literature, there are modern methods of transcending BIM information from site office to the real time on-site construction phase. Even though, operational site personal prefer the traditional method of communication, many researchers have attempted to bridge the communication gap between site office and construction site by introducing a number of novel technological techniques, especially related to the MCT. Table 2 illustrates the modern methods available to transcend BIM information to the on-site construction.

Table 2: Modern Methods Available to Use BIM at Site

No	Methods/ Devices	Source
1	Smart Phones	Ge and Kuester (2015)
2	Laptop PC	Ge and Kuester (2015), Kimoto *et al*. (2005)
3	Ultra-mobile PC	Papagiannakis and Magnenat-Thalmann (2007)
4	Handheld PC	Ge and Kuester (2015)
5	Palm size PC	Chen and Kamara (2008)
6	Tablet PC	Ge and Kuester (2015), Van Berlo and Natrop (2015)
7	Phablets	Ge and Kuester (2015)
8	Google glasses/ Head Mounted Display	Papagiannakis and Magnenat-Thalmann (2007)
9	iHelmets	Yeh *et al* (2012)
10	Large on-site touch screens	Sacks *et al*. (2010)
11	BIM kiosks/ Information booths	Hewage and Ruwanpura (2009)

8. RESEARCH METHODOLOGY

Even though, there is a topical necessity to study the research gap, the absence of BIM in the Sri Lankan construction industry has created a real barrier to develop a satisfactory research methodology. However, by overwhelming the challenge, a qualitative research approach was adopted to achieve the research aim. In order to proceed with the qualitative approach, semi-structured interviews were carried out as the data collecting technique. Due to the non-availability of BIM in the Sri Lankan context, the interviews were carried out in construction projects where highly innovating technologies were practiced. As the sample of the research, 5 projects were selected based on their particular characteristic as per the purposive sampling method. All these 5 projects were building projects where highly innovative technologies were adopted and they all were keen and had the capacity to implement BIM. Amongst them, 2 projects already had the BIM trace as the designing part of those projects were purely carried out through BIM.

After selecting the projects, semi-structured interviews were carried out targeting 3 site personnel namely site engineer, supervisor and worker who represented the top, middle and bottom levels in the traditional site communication hierarchy. No separate validation was carried out, but the validation was made by cross examining the opinions given by respondents from another respondents who represented the same level. This cross examining validation helped the researcher to extract an exact conclusion of the critical resisting factors from each level of respondents. After collecting the data, exploratory in-depth content analysis was conducted using a computer based content analysis software namely NVivo (version 10).

9. RESEARCH FINDINGS AND DISCUSSION

There were different opinions aroused from different respondents under each resisting factor. All these opinions were considered in the analysis, since none of the opinions could be ignored as those were the opinions that persuaded the site personnel to accept or reject the technology. However, the research aim was to identify probable challenges which barricade transcending of BIM information to real time on site construction. In order to achieve the research aim, the critical causes for RTC were extracted by using the pre-determined knowledge of literature findings and validations given by the respondents.

Finally, the overall knowledge gathered from the literature study and data collection were compiled together and demonstrated as a conceptual framework as illustrated in Figure 3. This clearly demonstrates the critical resisting factors of each level of site personnel towards the acceptance of MCT which can be used to bridge the gap between site office and real time on site construction in a BIM enabled construction project.

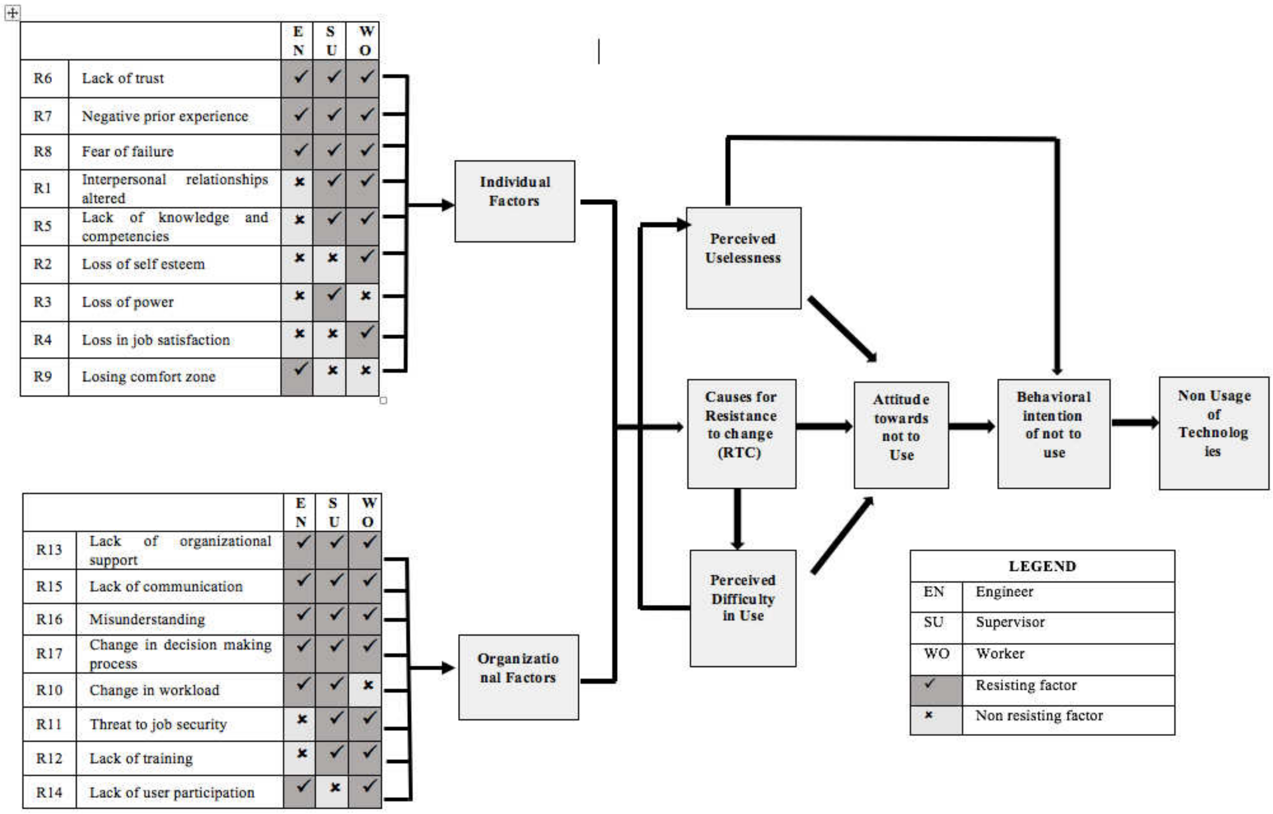

Figure 3: Conceptual Framework of Factors Effecting for RTC in BIM Enabled Real Time On-site Construction

In addition to aforementioned barriers, there were more important challenges which evolved from the opinions and reasoning expressed by the respondents under each resisting factor. The actual reasons as to why the respondents enthused to resist for MCT essentially created a new knowledge and can be expressed as an auxiliary research findings of the study. Thus, the tributary factors which evolved from the analysis can be exposed follows.

- Subordinates will become independent and do not follow instructions and decisions given by the superiors.
- No assurance of receiving right information to the right person
- Difficulty in finding the responsible party for any failure.
- Necessity of maintaining both modern and traditional methods together.
- Non-availability of infrastructure necessary for successful implementation.
- Failure to express expressions during the communication
- Poor integration with different stakeholders in the project.
- Possibility to misuse due to lack of knowledge and experience.
- Extensive generation gap
- Necessity to offer maximum supervision and attention on subordinates' works
- Possibility of occurring adverse consequences due to ability to transfer information and decision by passing the intermediate levels.
- Confusion on validity of receiving information.
- Complexity
- Failure to accomplish important user requirements.
- Possibility of reduction in supervision and instructions getting from the superiors
- Reduction in quality of work
- Responsibilities of each level will be wider and complex than earlier.

NEWLY DERIVED CAUSES FOR RESISTANCE TO CHANGE

Figure 4: Newly Derived Causes for RTC

Finally, the study has successfully distinguished the challenges faced by the operational level site personnel when implementing the MCT in a construction site. These challenges inevitably create a resistance within these individuals to reject the MCT and be trapped within the traditional paper based communication. Thus, it can be indirectly expressed that the research has successfully identified the challenges which barricade the transcending of BIM information from design phase to real time on site construction. Henceforth, the research findings accomplished the established research aim efficaciously and satisfactorily.

10. CONCLUSIONS AND RECOMMENDATIONS

BIM is a revolutionary concept which has procured a series of technologies to inspire the traditional AECO industry to become a modern and innovative industry. BIM integrated with MCT has made a viable solution to bridge the gap between site office and real time on site construction in a BIM enabled construction project. Even though, such integrated solution is available, operational level site personnel still prefer to be trapped within the boundaries of traditional communication. Henceforth, the main aim of this research was to identify the probable challenges which barricade the transcending of BIM from design phase to real time on site construction.

When discovering the challenges, it was found that the resisting nature of the site personnel is the main barrier for bridging this gap. Thus, 17 causes for RTC were identified and through semi structured interviews, the resisting nature of each personnel representing top, middle and bottom levels in the site communication hierarchy were assessed. From the research findings, it was found that the most resisting party is the operational workers in the site. Subsequently, the supervisors were the second highest resisting party in the site for a technological change related to the mobile computing. However, the site engineers who were considered to be the most educated and knowledgeable personnel at the site also expressed considerable amount of resistance to such a change. Finally, in addition to the existing knowledge on causes for RTC, more auxiliary causes for RTC were identified which were evolved from the reasoning and opinions given by the respondents.

This research purely gives the recommendations to the industry practitioners who realize the necessity of transcending BIM information from site office to the real time on-site construction. There are modern methods available to bridge this information gap, but it will require an extensive technological change within the site which will persuade the site personnel to resist. Therefore, the industry practitioners should cautiously make this transformation by implementing established change management concepts and with best organizational support.

11. REFERENCES

Bagranoff, N., Eighme, J. and Kahl, H., 2002. Who moved my ledger?. *The CPA Journal* [online], 72(10), 22-26. Available from: https://www.questia.com/magazine/1P3-219727151/who-moved-my-ledger [Accessed 14 July 2016].

Biranvand, V. P., Hakkak, M. and Nejad, O. N., 2015. Resistance to change in online banking and extension Technology Acceptance Model (TAM). *Bulletin of the Georgian National Academy of Sciences*, 9(1), 464-472.

Bordia, P., Hobman, E., Jones, E., Gallois, C. and Callan, V. J., 2004. Uncertainty during organizational change: Types, consequences, and management strategies. *Journal of Business and Psychology*, *18*(4), 507-532.

Chen, Y. and Kamara, J., 2008. The Mechanisms of information communication on construction sites. *Forum Ejournal*, 8(1), 1-32.

Cheng, F. P., Wang, K. H. and Lin, I. C., 2013. Measuring the adoption and resistance of E-learning by students. In: *International Conference on E-Technologies and Business on the Web (EBW2013)*, Bangkok. 247-249.

Chi, H., Kang, S. and Wang, X., 2013. Research trends and opportunities of augmented reality applications in architecture, engineering, and construction. *Automation in Construction*, 33, 116-122.

Davies, R. and Harty, C., 2013. Implementing 'Site BIM': A case study of ICT innovation on a large hospital project. *Automation in Construction*, 30, 15-24.

Davis, F. D., 1989. Perceived usefulness, perceived ease of use, and user acceptance of Information Technology. *MIS Quarterly*, 13(3), 319-340.

Davis, F. D., Bagozzi, R. P. and Warshaw, P. R., 1989. User acceptance of computer technology: A comparison of two theoretical models. *Management Science*, 35(8), 982-1003.

Eastman, C., Teicholz, P., Sacks, R. and Liston, K., 2011. *BIM handbook: a guide to Building Information Modelling for owners, managers, designers, engineers and contractors.* 2nd ed. New Jersey: John Wiley & Sons, Inc.

Egan, R. W. and Fjermestad, J., 2005. Change and resistance help for the practitioner of change. In: *38th Annual Hawaii International Conference on System Sciences*, 1-8.

Fishbein, M. and Ajzen, I., 1975. *Belief, attitude, intention, and behaviour: An introduction to theory and research* [online]. Available from: http://people.umass.edu/aizen/f&a1975.html [Accessed 14 July 2016]

Ge, L. and Kuester, F., 2015. Integrative simulation environment for conceptual structural analysis. *Journal of Computing in Civil Engineering*, 29(4), B4014004-1-B4014004-10.

Goh, K.C., Goh, H.H., Toh, S.H. and Peniel Ang, S.E., 2014. Enhancing communication in construction industry through BIM. In: *11th International Conference of Innovation and Management*, Finland. 23-25.

Hewage, K. N. and Ruwanpura, J. Y., 2006. Carpentry workers issues and efficiencies related to construction productivity in commercial construction projects in Alberta. *Canadian Journal of Civil Engineering*, 33(8), 1075-1089.

Hewage, K. N. and Ruwanpura, J. Y., 2009. A novel solution for construction on-site communication – the information booth. *Canadian Journal of Civil Engineering*, 36(4), 659-671.

Kerosuo, H., Miettinen, R., Paavola, S., Mäki, T. and Korpela, J., 2015. Challenges of the expansive use of Building Information Modelling (BIM) in construction projects. *Production*, 25(2), 289-297.

Kimoto, K., Endo, K., Iwashita, S. and Fujiwara, M., 2005. The application of PDA as mobile computing system on construction management. *Automation in Construction*, 14(4), 500-511.

Landles, E., 1987. Information technology and people: The challenge of change. *Journal of Information Technology*, *2*(2), 81-83.

Malato, L. A. and Kim, S., 2004. End-user perceptions of a computerized medication system: Is there resistance to change?. *Journal of Health and Human Services Administration, Summar (2004)*, *27*(1), 34-55.

Manzoni, J. and Angehrn, A. A., 1997. Understanding organizational dynamics of IT-enabled change: A multimedia simulation approach. *Journal of Management Information Systems*, 14(3), 109-140.

Mohamed, S. and Stewart, R. A., 2003. An empirical investigation of users' perceptions of web-based communication on a construction project. *Automation in Construction*, 12(1), 43-53.

Nov, O. and Ye, C., 2008. Users' personality and perceived ease of use of digital libraries: The case for resistance to change. *Journal of the American Society for Information Science and Technology*, 59(5), 845-851.

Oreg, S., 2003. Resistance to change: Developing an individual differences measure. *Journal of Applied Psychology*, 88(4), 680-693.

Pajo, K. and Wallace, C., 2001. Barriers to the uptake of web-based technology by university teachers. *Journal of Distance Education [online]*, *16*(1), 70–84. Available from: http://www.ijede.ca/index.php/jde/article/viewArticle/171/127 [Accessed 14 July 2016].

Papagiannakis, G. and Magnenat-Thalmann, N., 2007. Mobile augmented heritage: Enabling human life in ancient Pompeii. *International Journal of Architectural Computing*, 5(2), 396-415.

Raj, R. and Arokiaprakash, A., 2016 Application of technical advancement in the supply of structural design and drawings to improve the efficiency and adopting a best practice model to minimize delays in construction projects. *International Journal of Innovative Research in Science, Engineering and Technology*, 5(2), 2425-2457.

Sacks, R., Radosavljevic, M. and Barak, R., 2010. Requirements for Building Information Modelling based lean production management systems for construction. *Automation in Construction*, 19(5), 641-655.

Smith, H. A. and McKeen, J. D., 1992. Computerization and management: A study of conflict and change. *Information & Management*, *22*, 53-64.

Son, H., Park, Y., Kim, C. and Chou, J., 2012. Toward an understanding of construction professionals' acceptance of mobile computing devices in South Korea: An extension of the Technology Acceptance Model. *Automation in Construction*, 28, 82-90.

Tennakoon, H., 2009. *Factors influencing resistance to information technology related change in the telecommunication industry: A case study of Dialog Telecom [online]*. Thesis (MSc). University of Colombo. Available from: http://archive.cmb.ac.lk/research/bitstream/70130/1587/1/Hemamali%20Tennakoon%202009%20MISM%20037%5B1%5D.pdf [Accessed 20 July 2016]

Tessema, Y. A., 2008. *BIM for improved building design communication between architects and clients in the schematic design phase* [online]. Thesis (MSc). Texas Tech University. Available from: http://www.arch.ttu.edu/visualization/VIZ-Students-Web-Pages/2006-07/y.tessema/Thesis/Tessema_Yohannes_Thesis.pdf [Accessed 14 July 2016]

Timmons, S., 2003. Nurses resisting Information Technology. *Nursing Inquiry*, *10*(4), 257-269. doi:10.1046/j.1440-1800.2003.00177.x

Van Berlo, L. and Natrop, M., 2015. BIM on the construction site: Providing hidden information on task specific drawings. *Journal of Information Technology in Construction (ITcon), Special Issue: ECPPM 2014*, 20, 97-106.

Yeh, K., Tsai, M. and Kang, S., 2012. On-site building information retrieval by using projection-based augmented reality. *Journal of Computing in Civil Engineering*, 26(3), 342-355.

COMPARISON OF SUSTAINABLE MATERIALS FOR RAILWAY TRACK SUPPORT SYSTEMS: A LITERATURE REVIEW

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ABSTRACT

Timber transoms have been extensively used in the railway industry for decades and are considered the most efficient and effective in terms of reliability and performance for railway infrastructure transom components However, many studies have raised concerns surrounding the future of sustainable use and cyclic maintenance and replacement requirement of timber transom's in railway infrastructure Over the past decade, there has been significant research and development in alternative railway transom replacements using a variety of new materials. It is vital to develop a detailed understanding of existing and new alternative transom materials that are emerging into the railway industry and delineate whether these materials may be suitable as a sustainable alternative to traditional methods. Hence, the aim of this paper was to evaluate suitability of alternative transom materials as a substitute to existing transom materials in railway track support systems. The alternative materials considered were Precast Concrete and Composite Fibre Technology Panels against the conventional timber transforms. The paper offers a comparison between these materials through a literature review. It was concluded that the fibre composite alternative has the most beneficial alternative transom option and the railway industry could consider this material as an innovative, sustainable material for railway track support system.

Keywords: *Fibre Composite Technology; Precast Concrete; Railway Track Support Systems; Sustainability Timber Transforms.*

1. INTRODUCTION

The railway track support system is designed to interact with one-another to proficiently transfer imposed dynamic loading from the railway carriage wheels, through the support system and into the foundation (or other support system) (Esveld, 2001, Griffin *et al*., 2015, Kaewunruen and Remennikov, 2010, Remennikov and Kaewunruen, 2008). Railway infrastructure requires regular inspections to assess the service condition of each component of the tracks superstructure and the supporting substructure to ensure it is suitable operation. Transom inspection and replacement cycles must be efficient by balancing the opportunity to replace various components whilst the track is in possession of the maintenance crew, whilst also being cost effective (Krezo *et al*., 2014).

Railway sleepers are one of the most important elements of the railway system. Sleepers have the primary function of transferring and distributing lateral and longitudinal railway vehicle loads into the stratum below, and to provide a fixation point for maintaining a consistent gauge width of the railway tracks (Esveld, 2001, Manalo *et al.*, 2010, Remennikov and Kaewunruen, 2008). Commonly, in non-ballasted tracks, the sleeper components are referred to as 'transoms' or 'cross-ties', but still provide the same function as sleepers in ballasted track systems.

Timber sleepers and transoms have been used extensively for decades in the railway industry on an international scale (Esveld, 2001, Manalo *et al*., 2010, Sadeghi and Barati, 2012). Despite recent developments in alternative sleeper and transom materials, the mechanical properties in which timber inhibits make it the most effective railway track support component due to its ability to absorb and distribute the intense dynamic

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loading conditions (Manalo *et al*., 2010). However, in today's highly strenuous environment, timber materials experience issues with meeting its expected service life and concrete has now become the preferred sleeper and transom material.

In New South Wales, Australia, RailCorp (2013) produced an Engineering Standard - ESC Sleeper and Track Support - that provides specifications for timber and concrete sleepers, and polymer concrete half-sleepers. All transoms in non-ballasted tracks must meet the performance requirement set out in RailCorp's Engineering Standard - SPC 311 Timber Transoms - (RailCorp, 2009). This literature review provides further detail on the past, current and future developments in sleeper and transom support components. By identifying issues with existing transform materials, the literature intends to discuss new innovative alternative materials, their application and performance in railway infrastructure. The aim of this study was to evaluate suitability of these alternative transom materials as a substitute to existing transom materials in railway track support systems.

2. LITERATURE FINDINGS

2.1. TIMBER SLEEPERS AND TRANSOMS AND THEIR LIMITATIONS

Timber transoms have been extensively used in the railway industry for decades and are considered the most efficient and effective in terms of reliability and performance for railway infrastructure transom components (Rothlisberger, 2002, Zarembski, 1993). Timber transoms have been extensively used on an international scale as the primary rail support members for various types of railway service networks including regional freight systems, passenger rail services, light rail and even high speed rail services. Until recent developments in alternative materials, timber sleepers were the primary material used in typical ballasted track systems (see Figure 1 (a)). Timber is also used in non-ballasted track support and are commonly referred to as transoms or cross-tie components (see Figure 1 (b)) (Nunez, 2013).

(a)

(b)

Figure 1: (a) Timber Sleepers in Ballasted Railway System (B) Timber Transoms in a Non-Ballasted Railway System (Nunez, 2013).

Timber is primarily used as a railway transom support material due to its adaptability in terms of on-site workability, ease in handling and easy replacement (Manalo *et al*., 2010, Miura *et al*., 1998). In Australia, the average service life for timber transoms equates to approximately 20 to 30 years and this estimate is substantially effected by; the frequency and distribution of the loads imposed, the environment in which the transoms are exposed to, and the condition of the adjacent sleepers (Manalo *et al*., 2010, Yun and Ferreira, 2003).

Australian railway lines require more than 2.5 million timber sleepers per year for replacement alone (Manalo *et al*., 2010). Depending on how defective the transoms that have been replaced are, determines whether they are re-used, recycled or disposed of. Manalo *et al*. (2010) identified that the two most common defects resulting in sleeper replacement are (a) splitting and cracking, and, (b) fungal decay. In addition to these, Hagaman and McAlpine (1991) examined 2200 sleepers in Queensland, Australia and identified the following additional modes of failure for timber transoms which included, knot failure, localized rail cut at the fasteners, sapwood failure, general weathering, and in some cases termite damage.

Studies have raised concerns surrounding the future of sustainable use and cyclic maintenance and replacement requirement of timber transom's in railway infrastructure (Manalo *et al*., 2010, Miura *et al*., 1998, Qiao *et al*., 1998, Rothlisberger, 2002, Yella *et al*., 2009, Hagaman and McAlpine, 1991). Manalo *et al*. (2010) articulated that the most prevalent problem that the railway industry is now facing is the declining availability of quality timber for railway sleepers. Hardwood timber is becoming scarce and its quality is declining, which is making it less desirable for what was once considered a quality and renewable resource (Manalo *et al*., 2010, Robinson and Plywood, 2009).

Griffin *et al*. (2015) and Krezo *et al*. (2014)) identified that the replacement of timber transom components is responsible for producing six times greater greenhouse gas emissions than equivalent reinforced concrete counterparts. Esveld (2003) discussed that with the increasing need for timber transom replacement on ballasted railway tracks, the design of innovative support materials offers a good opportunity to minimise overbearing maintenance schedules and the demand for timber transoms which are becoming a highly sort-after product. This ideology reinforces the need for integrating alternative sleeper and transom materials such as Composite Fibre Technology.

The Australian Forest and Wood Product Statistics indicated that hardwood forestry in New South Wales, Australia has seen a decline in the total volume of timber harvested by 44% over the past decade (Timber NSW, 2015). The rate of renewal of hardwood timber species as transoms must be less than the rate of renewal for the product to be sustainable. Timber NSW (2015) described that a typical hardwood plantation takes 35 to 40 years to reach a level of maturity before it can be commercially logged. With the expected service life of timber transoms being only 20 years or less, it can be seen that the rate of renewal of hardwood timber species for timber transom replacement is not meeting the demands at a sustainable rate. With declining numbers of Australian hardwood species being harvested, this is threatening the sustainable ongoing use of the material.

Hazardous chemical products, such as ‘creosote’, have been used to extend the service life of the transom component. Thierfelder and Sandström (2008) indicated that creosote impregnated transoms can have an increase service life by up to nearly 50 years which is more than double that of a typical un-treated timber transom. However, there is a growing concern with the disposal techniques of creosote soaked timber sleepers when replacement is required (Manalo *et al*., 2010). Sinclair Knight Merz Pty Ltd and South Australian Environmental Protection Agency (1999) conducted a report for the Environmental Protection Authority (EPA) which identified that the disposal and re-use for treated timber has not yet been fully developed. Incineration is the most effective method of disposal, however, is cost prohibitive due to the chemical control requirements. Manalo *et al.* (2010) stated that “the New South Wales Environmental Protection Agency requires treated timber to be disposed of at engineered landfills with leachate management systems”. Alternatively, re-use applications of non-treated timber sleepers typically only include landscaping.

2.2. CONCRETE SLEEPERS AND TRANSOMS AND THEIR LIMITATIONS

The development of concrete transoms as an alternative to timber transoms has been widely implemented and accepted by the railway industry internationally, particularly for the use in high speed railway networks (Manalo *et al*., 2010, Sadeghi and Barati, 2012, Zarembski, 1993). Concrete sleepers were introduced in the 1980’s, and since then, various developments in conventionally reinforced and pre-stressed concrete transoms have been developed. Over the years, sleeper design has been focused specifically to maximise strength, durability and performance, whilst remaining low in cost and low in labour requirements. The average design life of concrete sleepers is 50 years and this far outweighs that of timber transoms 20 years (Ferdous *et al.*, 2015).

There has been a substantial development in the design of precast concrete sleepers and transoms resulting in an increased application in railway networks as track support components. In design, there has been an emphasis on efficiency during manufacturing, as well as encouraging methods for better onsite handling practices. All concrete sleepers are generally precast and transported to site for placement. Concrete sleepers are beneficial for use in railway track support as they provide economic and technical advantages with increased service life and an overall reduced maintenance costs (Manalo *et al*., 2010). Despite concrete sleepers being more durable and reliable in service than timber counterparts, Manalo *et al*. (2010) indicated that concrete sleepers are far too expensive, quite heavy and are often incapable of meeting the 50 year service life. However, contrary to this, Crawford (2009) articulated that with proper maintenance of rails, pads, fastenings, ballast and sub-grade, concrete transoms can quite easily meet their anticipated 50 year design service life. (Bureau of Transport Economics (1972), Manalo *et al*. (2010)) showed concern that the substantial weight difference between timber transoms and reinforced concrete was a significant disadvantage for the materials adopted use.

Concrete transoms are substantially higher in cost to produce than timber transoms (Bureau of Transport Economics (1972), Ferdous *et al*. (2015), Manalo *et al*. (2010), Sadeghi and Barati (2012)). They are more than three times the weight of a traditional timber transom, and susceptible to 'bending cracks' from highly intense dynamic loading of passing locomotives, as well as 'sleeper breakage due to derailment' (Zakeri and Rezvani, 2012). However, Raju (2006) identified that the percentage of failures due to cracking of sleepers is in order of 1% in German railway lines for the design life of the sleepers.

The substantially larger outlay costs for purchasing concrete transoms is more than double the cost for equivalent timber transoms. This puts a negative stigma around the use of this material due to scarcity of funds (Sadeghi and Barati, 2012). However, various comparative studies between concrete and timber transoms recognise that the maintenance cost is substantially reduced as a result of the improved serviceable performance (du béton, 2006, Manalo *et al*., 2010, Zarembski, 1993).

Concrete constructed transoms are now considered as a traditional method of railway construction. However, their design efficiency in production and on-site handling is yet to be refined for optimum performance ergonomically and practically. The Australian railway networks have seen concrete systems being widely implemented as an alternative to timber sleepers in both ballasted track systems (Lo, 2014) and the use of slab tracks in non-ballasted systems, specifically in bridges and tunnels (Bilow and Randich, 2000). A number of comparative studies have been conducted comparing timber and concrete as sleeper materials, however these studies have not examined the LCC benefit of using Composite Fibre as sleeper material (Bureau of Transport Economics, 1972, Ferdous *et al*., 2015, Manalo *et al*., 2010, Sadeghi and Barati, 2012). This reinforces the purpose of this study to undertake a LCC analysis of utilising CF technology.

2.3. FIBRE COMPOSITES AND THEIR POTENTIAL FOR SLEEPERS AND TRANSOMS

A number of new alternative technologies have been developed as transom replacement solutions, and yet their introduction into the railway industry has been very limited. This section aims to highlight innovative sustainable sleeper and transom technologies, in particular fibre composites, and discuss their benefits and applications as new or replacement transom and sleeper components.

The key benefit of using reinforced fibre composites sleepers is that they can be designed to imitate the structural action of a timber transom components. They have the ability to be integrated as a replacement component in an existing system and are far more effective than concrete or steel (Van Erp and Mckay, 2013). However, Van Erp and Mckay (2013) indicated that the introduction of Fibre Composites to Australian railways has been limited despite the many benefits. The price of FC materials are approximately 5-10 times higher than a standard timber sleeper making them commercially unviable (Van Erp and Mckay, 2013). However, due to significant reduction in maintenance requirements, cost savings are expected in the longer run.

Fu and Lauke (1996) concluded that the effects of fibre length distribution and fibre orientation distribution has identified a vital role in the strength characteristics of fibre composite components. Ferdous *et al*. (2015) identified that there are various types of fibre composite sleepers available in the railway industry, each of which have varying fibre compositions in terms of length, orientation as well as the addition of filler materials. These fibre composite railway sleepers are categorised into three different types due to their material composition.

- Type 1 fibre composite sleepers have short or no glass fibre reinforcement with the addition of filler materials including bitumen or recycled plastics (Ferdous *et al*., 2015, Van Erp and Mckay, 2013).
- Type 2 fibre composite sleepers have long continuous longitudinal glass fibres creating great flexural strength (Ferdous *et al*., 2015, Van Erp and Mckay, 2013). Ferdous *et al*. (2015) stated that these (Type 2) sleepers are suitable for ballasted rail track where the stresses in sleepers are governed by flexural loading. However, they are less than ideal in bridge applications as transom components where they are subjected to high level of combined flexural and shear forces.
- Type 3 sleepers have fibre reinforcement in longitudinal and transverse directions and consequently both the flexural and shear strength of these polymer sleepers is significantly increased (Ferdous *et al.*, 2015). This makes Type 3 fibre composite products more desirable as a bridge transom component.

2.4. APPLICATIONS OF FIBRE COMPOSITES IN AUSTRALIA AND INTERNATIONALLY

Van Erp and Mckay (2013) stated that both Type 1 and Type 2 fibre composite polymer sleepers had been introduced into the Australian market. Van Erp *et al*. (2005) indicated that Queensland Rail had implemented trial fibre composite polymer sleepers in April 2004. More recently, Van Erp and Mckay (2013) stated that an Australian Fibre Composite product called ‘CarbonLoc’, a type 2 sleeper, had been installed in a Railway bridge as transom components in the Hunter Valley. CarbonLoc is referred to as a Fibre-reinforced Foamed Urethane (FFU) product due to its material composition. FFU characteristically acts similarly to timber enabling the material to be integrated into the existing system with ease (Koller, 2015). FFU is easily workable for handling and processing (Koller, 2015). Koller (2015) indicated that in Japan, an investigation was carried out into FFU sleepers that had been installed and in operation for 30 years. The results concluded that the FFU sleepers would still be serviceable for a further 20 years.

The key characteristic that separates Fibre Composites from other transom materials (i.e. concrete, steel and timber) in railway networks is that fibre composites offer 40% better strength characteristics in comparison to their weight (Van Erp and Mckay, 2013). This offers many benefits in relation to onsite handling processes, transportation to site, and reduced dead-load on the existing structural support system. Other benefits include exceptional installation times in comparison to concrete counterparts, longer service life, reduced maintenance, excellent corrosion resistance and with the use of plant-based-based polymers, the effect on the environment is minimal (Van Erp and Rogers, 2008).

A new, Type 3 fibre composite polymer (CFT) product was developed in response to the need for sustainable building solutions for existing and new structural components in various industry sectors. Van Erp and Rogers (2008) showed that the new material has major environmental benefits over traditional construction materials. It uses only a fraction of the energy in the manufacturing process compared with traditional construction materials and is carbon neutral. The material has extensive uses in the building market as well as uses in bridge construction and maintenance. Bakis *et al*. (2002) stated that the forms of fibre composite polymer (CFT) construction materials has more advantage with the perceived near-term economic and sustainable benefits of the materials. CFT has been integrated as replacements for existing heavy structural components, and as new structural elements for various new designs (Queensland Government, 2013) and has been used for conveyor-belt systems in the mining industry, new road bridges and rehabilitation of existing timber bridges, and in pedestrian walkway structures (Wagners CFT, 2016). It has also been utilised in marine environments as support structures, electrical cross-arms of high-voltage towers, and as reinforcement in concrete slabs (Wagners CFT, 2016). Table 1 provides a comparison of the different railway materials discussed above.

Overall, it is evident through this literature review on the need for the application of alternative materials for railway support structures. Timber sleepers and transoms are functional in service due to their ability to absorb locomotive loads, however they are incapable of meeting their design life. Monobloc concrete sleepers provide superior strength and increased service life in comparison to timber, however they are expensive, heavy to manoeuvre onsite, and experience brittle failure. Fibre Composites offer the strength characteristics of concrete and steel, the design life is far more superior, and the maintenance requirements are far less. With the limited introduction of Fibre composite transoms (in particular, Type 3) into Australian Railway systems, ongoing costly maintenance requirements that are experienced with timber and concrete materials could be overcome and thereby address the environmental issues.

Table 1: Comparison of Transom and Sleeper materials

Criteria	Timber Sleepers and Transoms		Concrete Sleepers and Transoms		Composite Fibre Sleepers and Transoms	
	Advantages	Disadvantages	Advantages	Disadvantages	Advantages	Disadvantages
Properties	Good mechanical behavior Light-weight	Prone to cracking/ splitting Experience fungal decay Termite attack	Monolithic structural action.	Experience cracking. Experience breakage due to high dynamic loading	Good mechanical behavior for trains (similar to timber) Lightweight and corrosion resistant	Degrades strength when exposed to direct sunlight Protective paint required to limit solar exposure
Durability	Durable in optimum locations	Often incapable of meeting design life (20 years)	Durable (capable of meeting 50yr design life).		Durable (expected 100 year design life)	
Cost	Cheap in capital cost	High maintenance costs	Pre-cast manufacturing for efficient transportation.	High capital cost to purchase	Pre-cast manufacturing for efficient transportation.	High capital cost to purchase
Sustainability	Re-usable for other applications (landscaping, building etc.)	Declining volume of hardwood available to meet rate of renewal.	Constructed from recyclable materials.	High carbon emissions during manufacturing.	Readily available resources	Limited use due to emerging nature

3. CONCLUSIONS

The aim of this paper was to evaluate alternative transom materials as a substitute to existing transom materials in railway track support systems. The alternative materials considered were Precast Concrete and Composite Fibre Technology Panels against the conventional timber transforms. Based on the literature findings, it can be concluded that the fibre composite alternative has the most beneficial alternative transom option. The results dictate that transom materials with higher design life, higher capital costs, less installation time, and less maintenance requirements is more beneficial than less expensive alternative materials that require more maintenance and high labour costs required to perform maintenance operations. The composite fibre alternative offers increased service life, faster installation process and less overall long term maintenance expenditure, as well as offering a significantly less dead-load on the structure (than concrete alternatives).

4. REFERENCES

Bakis, C. E., Bank, L. C., Brown, V. L. and E., C., 2002. Fiber-Reinforced Polymer Composites for Construction—State-of-the-Art Review. *Journal of Composites for Construction*, 6(2), 73-87.

Bilow, D. N. and Randich, G. M., 2000. Slab track for the next 100 years. In: *Proceedings of American Railway Engineering and Maintenance of Way Association.*

Bureau of Transport Economics. 1972. *Economic Evaluation of Timber and Concrete Sleepers for Three Railway Lines: Tarcoola-Alice Springs, Adelaide-Crystal Brook and Trans-Australian Railway*. Australia.

Crawford, R. H. 2009. Using life cycle assessment to inform infrastructure decisions: the case of railway sleepers. In: *6th Australian Conference on Life Cycle Assessment*, Melbourne, Australia.

du béton, F. 2006. Precast Concrete Railway Track Systems: *State-of-art Report*. International Federation for Structural Concrete.

Esveld, C. 2001. *Modern railway track*. In D. Zwarthoed-Van Neiwenhuizen (Ed.), (Second Edition ed., pp. 14 - 632). Netherlands: Delft University of Technology.

Esveld, C. 2003. *Recent developments in slab track. European railway review*, 9(2), 81-85.

Ferdous, W., Manalo, A., Van Erp, G., Aravinthan, T., Kaewunruen, S. and Remennikov, A. 2015. Composite railway sleepers–Recent developments, challenges and future prospects. *Composite Structures*, 134, 158-168.

Fu, S.-Y. and Lauke, B. 1996. Effects of fiber length and fiber orientation distributions on the tensile strength of short-fiber-reinforced polymers. *Composites Science and Technology*, 56(10), 1179-1190.

Griffin, D., Mirza, O., Kwok, K. and Kaewunruen, S. 2015. Finite element modelling of modular precast composites for railway track support structure: A battle to save Sydney Harbour Bridge. *Australian Journal of Structural Engineering*, 16(2), 150-168.

Hagaman, B. and McAlpine, R. 1991. ROA timber sleeper development project. In: *Conference on Railway Engineering 1991: Demand Management of Assets*, Adelaide 23-25 September 1991. Preprints of Papers.

Kaewunruen, S. and Remennikov, A. 2010. Dynamic properties of railway track and its components: recent findings and future research direction. *Insight-Non-Destructive Testing and Condition Monitoring*, 52(1), 20-22.

Koller, G. 2015. FFU synthetic sleeper – Projects in Europe. *Construction and Building Materials,* 92, 43-50.

Krezo, S., Mirza, O., He, Y., Kaewunruen, S. and Sussman, J. M. 2014. *Carbon emissions analysis of rail resurfacing work: a case study, practical guideline, and systems thinking approach.*

Lo, C. 2014. Railway Sleeper Facts. *The Way Forward? Wood, Concrete, Steel or Plastic?* Available from: http://www.railwaysleepers.com/railway-sleepers/railway-sleeper-info/railway-sleeper-facts [Accessed 14 May 2016].

Manalo, A., Aravinthan, T., Karunasena, W. and Ticoalu, A. 2010. A review of alternative materials for replacing existing timber sleepers. *Composite Structures*, 92(3), 603-611.

Miura, S., Takai, H., Uchida, M. and Fukada, Y. 1998. The mechanism of railway tracks. *Japan Railway and Transport Review*, 3, 38-45.

Nunez, J. 2013. *Crossties can be made from a variety of materials and all parts of the industry report strong growth in 2013.* Available from http://www.rtands.com/index.php/track-structure/ballast-ties-rail/annual-crosstie-report-2013.html [Accessed 6 April 2016].

Qiao, P., Davalos, J. F., and Zipfel, M. G. 1998. Modeling and optimal design of composite-reinforced wood railroad crosstie. *Composite Structures*, 41(1), 87-96.

Queensland Government. 2013. *Wood Properties and uses of Australian Timbers.* Available from https://www.daf.qld.gov.au/forestry/using-wood-and-its-benefits/wood-properties-of-timber-trees [Accessed 8 April 2016]

RailCorp. 2009. *SPC 311 - Timber Transoms Engineering Specification*. New South Wales, Australia: Asset Standards Authority.

RailCorp. 2013. *ESC - 230 Sleepers and Track Support Engineering Standard - Track.* New South Wales, Australia: Asset Standards Authority.

Raju, N. K. 2006. *Prestressed concrete* (M. Narayanan Ed. 4th ed.). India: McGraw-Hill Education Pvt Limited.

Remennikov, A. M. and Kaewunruen, S. 2008. A review of loading conditions for railway track structures due to train and track vertical interaction. *Structural Control and Health Monitoring*, 15(2), 207 - 234.

Robinson, P. and Plywood, B. 2009. Innovation in Engineered Wood Product Bridge Components. In: 7th *Austroads Bridge Conference*, 2009, Auckland, New Zealand.

Rothlisberger, E. S. 2002. *History and Development of the wooden sleeper*. 2.

Sadeghi, J. and Barati, P. 2012. Comparisons of the mechanical properties of timber, steel and concrete sleepers. *Structure and Infrastructure Engineering*, 8(12), 1151-1159.

Sinclair Knight Merz Pty Ltd, and South Australian Environmental Protection Agency. 1999. *Review of the Landfill Disposal Risks and Potential for Recovery and Recycling of Preservative Treated Timber* (pp. 52). New South Wales, Australia.

Thierfelder, T. and Sandström, E. 2008. The creosote content of used railway crossties as compared with European stipulations for hazardous waste. *Science of The Total Environment,* 402(1), 106-112.

Timber NSW. 2015. *Timber: A Reneable Resource?* Available from http://timbernsw.com.au/debunking-myths/ [Accessed 22 April 2016]

Van Erp, G., Cattell, C. and Heldt, T. 2005. Fibre composite structures in Australia's civil engineering market: an anatomy of innovation. *Progress in Structural Engineering and Materials*, 7(3), 150-160.

Van Erp, G. and Mckay, M. 2013. Recent Australian developments in fibre composite railway sleepers. *Electronic Journal of Structural Engineering*, 13, 62-66.

Van Erp, G. and Rogers, D. 2008. A highly sustainable fibre composite building panel. In: *Proceedings of the international workshop on fibre composites in civil infrastructure–past, present and future.*

Wagners CFT. 2016. *Wagners Composite Fibre Technologies*. Available from http://www.wagnerscft.com.au/ [Accessed 14th May, 2016]

Yella, S., Dougherty, M. and Gupta, N. K. 2009. Condition monitoring of wooden railway sleepers. *Transportation Research Part C: Emerging Technologies,* 17(1), 38-55.

Yun, W. Y. and Ferreira, L. 2003. Prediction of the demand of the railway sleepers: A simulation model for replacement strategies. *International Journal of Production Economics*, 81–82, 589-595.

Zakeri, J.-A. and Rezvani, F. H. 2012. Failures of railway concrete sleepers during service life. *International Journal of Construction Engineering and Management,* 1(1), 1-5.

Zarembski, A. M. 1993. Concrete vs. wood ties: making the economic choice. In: *Conference on maintaining railway track: determining cost and allocating resources*, Arlington, VA.

COMPUTER BASED MODEL TO CHANGE OCCUPATIONAL SAFETY & HEALTH AND ENERGY MANAGEMENT ATTITUDES OF OCCUPANTS IN THE GARMENT INDUSTRY

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ABSTRACT

Garment industry is one of the major contributors to the Sri Lankan economy. Nonetheless, productivity of the industry is crucially influenced by Occupational safety and health (OSH) and Energy management (EM) mal-behaviours. Even within the industry, behaviour of sewing machine operators are vital. It is noted that that industry is the second most contributor to the OSH accidents. Further, energy demand for the manufacturing is a major concern. In fact, it is notable that these two areas can be enriched by altering personnel attitudes, which will ultimately affect to the behavioural patterns. There are varieties of tools to change attitudes of people in order to change their behaviours. Computer models can be considered as a modern approach. Thus, this research focuses on current common behavioural issues and brings-up a computer model as a solution

Consequently, the research concludes findings obtained through preliminary investigation and a semi structured questionnaire survey that was conducted upon, behavioural issues and applicability of computer model respectively. Preliminary investigation consists of two surveys; expert opinion survey and structured questionnaire survey.

Ten number of issues were confirmed. Not wearing PPEs, poor sitting positions, removing safety devices of the machine and not switching off probe lights and machine were noted as top three significant issues. In computer model, top two accepted aspects were scoring mechanism and monitory gifts for winners.

Keywords: *Attitudes and Behaviours; Attitude Change; Computer Based Model; Energy Management; Occupational Health and Safety.*

1. INTRODUCTION

EM and OSH are two different areas that are vital for the garment manufacturing industry (Dheerasinghe, 2003). Nevertheless there are many occupational accidents in the garment manufacturing industry in Sri Lanka (Dissanyake and Fonseka, 2014). Similarly, on the other hand, ultimate product price is influenced by the energy costs (Samarasinghe *et al*., 2015). Furthermore, both of these areas are actively engaged in the production areas, where sewing works are carried-out (Dalia *et al*., 2014; Padmini and Venmathi, 2012). Hence, behaviours relating to OSH and EM are important (Dheerasinghe, 2003).

Martins *et al*., (2016) stated that computer model have a positive impact on a psychology of a person. Similarly, Orland *et al*. (2014) mentioned that people’s ability to think, managerial and conceptual skills, designing, and familiarise to the environment can be improved through computer games.

Currently in Sri Lanka, younger generations are more into the computer technology (Department of Census and Statistics [DCS], 2015). This was a positive point to implement a computer model to improve behaviours by changing attitudes of a person. Therefore, comprehensive literature review was carried out in the next section followed my methodology chapter. Finally, the study presents research findings and discussion followed by conclusions and recommendations.

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2. LITERATURE FINDINGS

2.1. OCCUPATIONAL SAFETY AND HEALTH (OSH) IN GARMENT INDUSTRY

OHS is primarily concerned about refining the health of employees and ensure their protection during working hours (Goetzel *et al*., 2008). There are around 4000 incidents in garment manufacturing industry per year resulting to lose more than 600000 working days (Dissanyake and Fonseka, 2014). OSH is vital for the reputation and product cost of a garment factory (Samarasinghe *et al*., 2015). However poor attitudes have identified as a primary cause for accidents (Almén and Larsson, 2014). Table 1 illustrates the identified OSH related behavioural issues of workers in garment industry.

Table 1: Behavioural Issues of Workers Related to OSH

No.	Source	Issue
I1	Calvin and Joseph (2006)	Employee meet needle stick Injuries due to poor behaviours
I2	Bandara (2010)	Employee is electrocuted due to carelessness
I3	Calvin and Joseph (2006)	Employee keep objects on floor and hence slip/trip/falls
I4	Serinken *et al.* (2012)	Employee touches hot surface and get burned
I5	Serinken *et al.* (2012)	Employee get Injured due to mechanical parts of machine other than needle stick injuries
I6	Calvin and Joseph (2006)	Employee doesn't try to wear PPEs
I7	Lombardo (2012)	Employee doesn't avoid poor sitting positions
I8	Bashiri (2014)	Employee doesn't avoid high lighting levels
I9	Padmini and Venmathi (2012)	Employee doesn't avoid foreign body (Dust/Fumes)
I10	Padmini and Venmathi (2012)	Employee doesn't avoid higher noise levels
I11	Padmini and Venmathi (2012)	Employee doesn't avoid hot environment

2.2. ENERGY MANAGEMENT (EM) IN GARMENT INDUSTRY

Sri Lankan garment sector subjected to the high-power consumption which result product price goes-up (Samarasinghe *et al*., 2015). Nevertheless, supply chain of apparel is affected with energy and other additional costs in factories (Jayawickrama and Thangavelu, 2011). However, personal behaviours are critically attributed to energy consumption patterns (Yang *et al*., 2015). Hence attitudes of people towards EM should be changed. Table 2 illustrates the identified EM related issue list.

Table 2: Behavioural Issues of Workers Related to EM

No.	Source	Issue
I12	SLSEA (2009)	Employee do not switch off lights when leaving
I13	Padmini and Venmathi (2012)	A/C set temperature level is kept less than 25 degrees Celsius
I14	Padmini and Venmathi (2012)	Employee do not switch off A/C when leaving
I15	BOI (2011)	Requiring of excessive lighting exceeding required amount
I16	Islam (2016)	Machines are set to high RPM rates when working, by employees
I17	Darabnia and Demichela (2013)	Poor sewing machine maintenance by Employees
I18	Abdoli and Semere (2014)	Employees do not switch off machine when leave
I19	Dalia *et al*. (2014)	Removing compressed air tubes of machine for other purposes other than expected purpose; pneumatic supply for machine

2.2 Change Attitude towards Behaviours

Behaviour is the action of an individual may take (Coon and Mitterer, 2013). Further, attitude is a psychological propensity which is unique for each individual based upon their desires (Shook and Bratianu, 2008). Moreover, attitudes of one person are subjected to the behaviours of other people (Ajzen, 2015). One of best method to change behaviours is through administrative punishments and rewarding (Lardner, 2015). According to Ajzen (2015) sometimes past memories of people are cause for attitude changes. However Ajzen (2015) stated that self-intention is required to change attitudes. Similarly, Rogers (2003) highlighted that an innovative ideas have ability to change attitudes of a person. Motivation is also an attitude changing approach (Ajzen, 2015). These are the past attitude changing approaches that an employee may perceive.

It is apparent that number of researches have focused on different computer based models in order to change the workers attitude and behaviours towards working process. Thus, Bang *et al*., (2006) introduced a computer game, "power house" to change behavioural pattern in order to save energy. A good computer model, "Energy Chicken" were introduced by a group of people to conserve the energy pattern and got 13% of electrical consumption savings (Orland *et al*., 2014). Similarly, computer games were used to improve the OSH in industries. Guo *et al*., (2012) introduced a computer game model to improve the safety of the workers. Nevertheless, it is proved that computer games can improve the health outcomes (Primack *et al*., 2012). Hence computer game models can be used to improve either OSH or EM related behavioural issues.

Further, in Sri Lanka, employees are motivated by giving compensation, gifts, financial benefits or rewards (Pratheepkanth, 2016). However, Current overall computer literacy in Sri Lanka is 24.6% and there is a 9.8% growth compare to the year 2014 (DCS, 2015). Hence it can be clearly identified that computer literacy is improving and it ultimately result to the progress of the model.

2.3 Features of Computer Models

Success of a game depends on the technology that used to design multimedia effects (Chen *et al*., 2005). Nevertheless, creativity of the game is immensely contributed to the success of a game (Vanhala *et al*., 2015). Chen *et al*., (2016) argued that, perceived amusement through the game is vital to attract many people. Hence it is clear that high quality graphics will render the success of a game. Moreover, there are several areas that have to be concerned. Game value motivates the players to play the game and discover game more and more (Shi and Shih, 2015). It primarily depends on the preferences of the players (Park and Lee, 2011). Game fantasy stands for the environment of a game or the background of a game (Tamborini and Skalski, 2016). Game goals are the targets of the game (Swartout and Lent, 2003). Interaction means, how the player communicates with the game and level of the communication (Shi and Shih, 2015). Game mechanism is the pathway or a technique to achieve the goal (Shi and Shih, 2015). Challenge is the test given for the player (Rieber and Noah, 2008). Multimedia effects are highly useful to achieve this target (Huang *et al*., 2013).

Computer model is driven through a score system. Score systems are described under the section 2.5.If organisation intended to raise-up its productivity, then the best option would be performance evaluation (Karuhanga, 2015). Auditing is a high quality process of detecting and reporting the data related to activities (Mohamad and Habib, 2013). According to authors audit is a method to ensure that the implemented activities or the processes work properly. Therefore, it is apparent that there are significant factors such as game value, game fantasy, game goals, game mechanism, auditing and score system to be considered when developing a computer based game model to change the attitudes of the workers in particular industry.

3 Computer Model

Following computer model was developed based upon the findings of the literature review. This computer model does not affect to employees’ day to day work routine. Supervisors evaluate whether the employees are committing an issue or not. Figure 1 present the interface of the developed computer model.

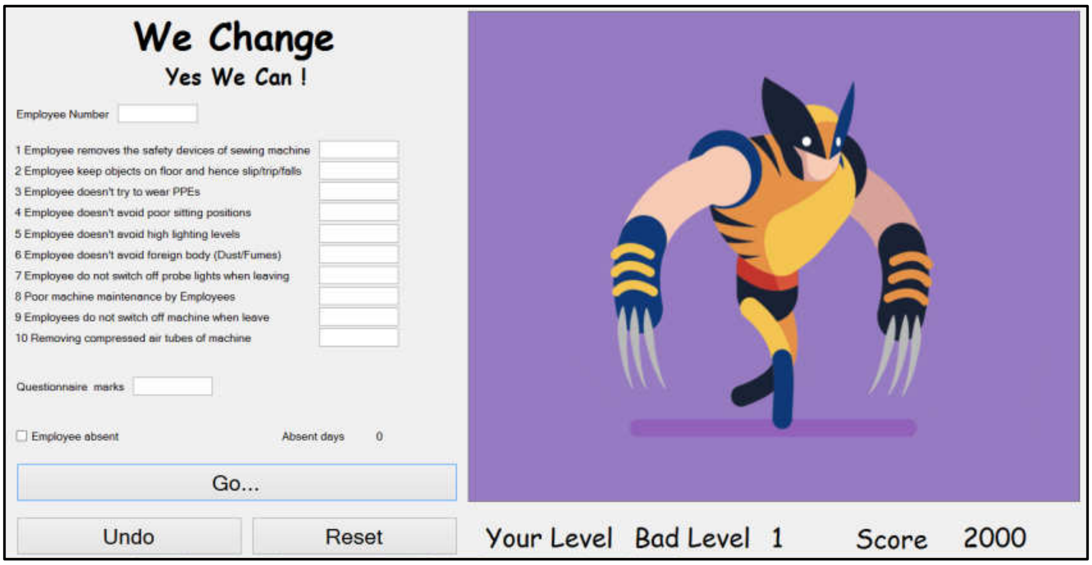


Figure 1: Interface of the Computer Model

Computer model itself provided a comprehensive OHS related issues and EM related issues frequently done by the employees. The evaluation is based on the frequency of occurrence of a particular issue by particular employee and the score system developed at the section five of the research paper.

Each user has been assigned a unique character. In the beginning, this character is appeared as good and aesthetic. When a user commits a poor behaviour, his/her total mark (2000) will begin to reduce gradually. Initially a set score of 2000 points are added to the system. These 2000 score is valid only for one month. However, these points are subjected to the poor behaviours of employees. Each behavioural issue related to OHS and EM is assigned a unique value. This unique value is obtained through the data analysis based on the questionnaire survey regarding the OHS and EM related behavioural issues. Based on the answers given by the experts, issues were prioritised according to the mean values. These values are considered as negative values. These negative values are to be added to the total score (2000).

There are four (4) levels in the game currently. These levels are named as “Bad Level”. To complete a “Bad Level”, user need to collect 200 negative points that are resulted due to the bed behaviours. When the users’ negative points increase, “Bad Level” of the character in this game will be gradually increased. Higher “Bad level” means, these users have committed numerous poor behaviours.

There are two weightages for score system. One weightage is dedicated for the type of the behavioural issue whereas the other weightage is dedicated for the character level. When user goes one “Bad Level” to another, his/her OHS and EM related behaviours are subjected to higher weightage. Hence his/her negative values will be increased though he committed the same mistake as similar to the previous levels. This feature is added to prevent doing the same mistake again and again. It is assumed that the user will not commit any more poor behaviour in order to save his/her current score. User, who achieves the highest score, as mentioned under the Eq. 1, will be awarded. Highest score can be defines as the Peron who stays in the lowest “Bad Level”. Nevertheless, ultimate score is the combination of both negative marks and initial marks (refer Eq. 3).

Employee may be absent for days. If the employee absent for more than 3 days, his/her character will be temporary disabled until the next round. For less than 3 days absentees, their total average negative points till the absent days will be added for absent day (refer equation 3).

Obtained total negative points (TNP) = $\sum_{i=1}^{n}\{W_i(\sum_{k=1}^{l}(N_k I_k))\}$ *(Eq: 01)*

Where, W = weightage per level (level 1= 1.1, level 2= 1.2, level 3= 1.3 and level 4 = 1.4), n = number of levels, i = number of behavioural issues types (refer Figure 4), I = Negative value per type of issue (depend on garment factories), and N= count of the issue corresponding to I

Absent day negative score = TNP till absent day/ worked days *(Eq: 02)*

Total Score = 2000 + TNP *(Eq: 03)*

4 RESEARCH METHODOLOGY

Research can be identified as a combination of activities including investigation procedures, possible ways of happening, understanding the principle, testing and analyse the solutions (Kumar, 2011). In here, two approaches have been followed; qualitative and quantitative. Nevertheless, research process is a path which is taken by people when they got a question and how they answer it (Kumar, 2011). As the initial stage, it was stated the problem, interested areas and subject matters briefly. Secondly Literature survey was carried-out to provide framework for the research and as well as benchmarks to compare research findings. Computer model was developed by considering the facts described under literatures survey.

Preliminary investigation consists of expert survey as the first part of it. It was conducted to obtain the opinions of the experts in garment manufacturing industry regarding identified mal-behaviours. Three (3) experts were selected from the same industry for the purpose of refining the identified issues. Second part of the preliminary investigation consists of a structured questionnaire. It was used to prioritise the behavioural issues which were already refined under the expert questionnaire survey. Therefore 30 questioners were distributed among the experts and requested to mark the significance of each behavioural issue in order to rank them. A semi structured questionnaire survey was conducted to review the concept of computer based model. 30 questionnaires were distributed among the experts and requested to mark the suitability of each feature of the computer model.

Data analysis consists of three preliminary functions; data preparation, analysis and discussion of results (Kumar, 2011). Both qualitative and quantitative data were analysed. N-Vivo software was used to analyse qualitative data. Quantitative data was analysed to compute Mean and Standard deviation (STD) using Microsoft excel and IBM SPSS. Mean is the average of the responses and STD defines of how the members deviate from the mean (Kumar, 2011). Relative importance index (RII) technique was used to analyse the relative importance of the factors by cross comparing it (Muhwezi *et al*., 2014). According to authors, it is considered that issues which has got RII value greater than 0.599 (RII>0.599) are considered as significant factors whereas the rest are noted as the not significant factors

$$\textit{Mean}\ (\bar{x}) = \frac{\sum x}{n} \qquad \textit{(Eq: 04)}$$

Where, x = response value and b = number of responses

$$\textit{Standard Deviation (STD)} = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}} \qquad \textit{(Eq: 05)}$$

Where, x = response value, $\bar{x}$ = mean and b = number of responses

$$\textit{Relative Importance Index (RII)} = \frac{\sum_{i=1}^{n} P_i W_i}{An} \qquad \textit{(Eq: 06)}$$

Where, A = highest allocated integer weight, n = sample size, W = number or similar response on each weight class and P= weight relating to the corresponding responses (W)

5 DATA ANALYSIS

First part of the data analysis is consists of an expert opinion survey. Based on the opinion of them, I4, I5, I13, I14 and I16 were removed from the list (refer Table 2) with clear reasoning and I1 and I12 were updated. I1 was improved as employee removes the safety devices of the machine and I12 were improved as employee may no switch-off probe lights when leaves. With this survey, identified issues were refined according to the Sri Lankan context.

Structured questionnaire prioritised the refined behavioural issues. As per the RII analysis, issues that have obtained more than 0.6 were removed from the list. Therefore, I1, I3, I6, I7, I8, I9, I12, I17, I18 and I19 were regarded as critical issues. Figure 2 illustrates the analysis of Mean and STD of the structured questionnaire. Figure 3 illustrates the RII for EM and OSH related behavioural issues

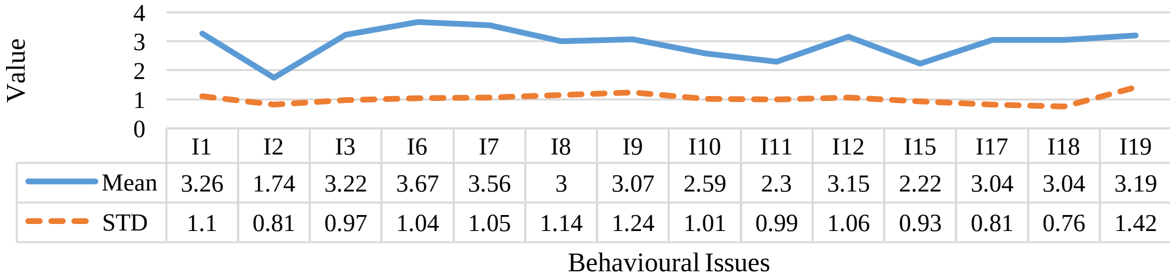


Figure 2: Mean and STD of Behavioural Issues

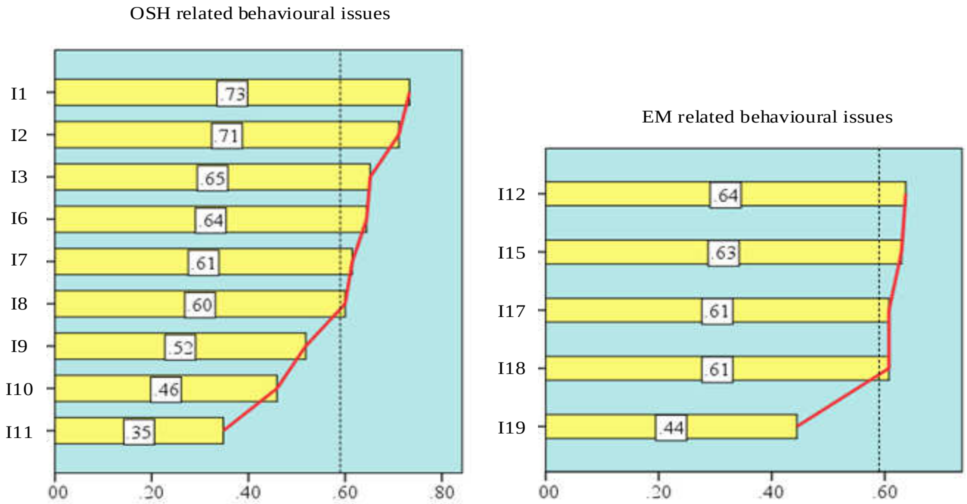
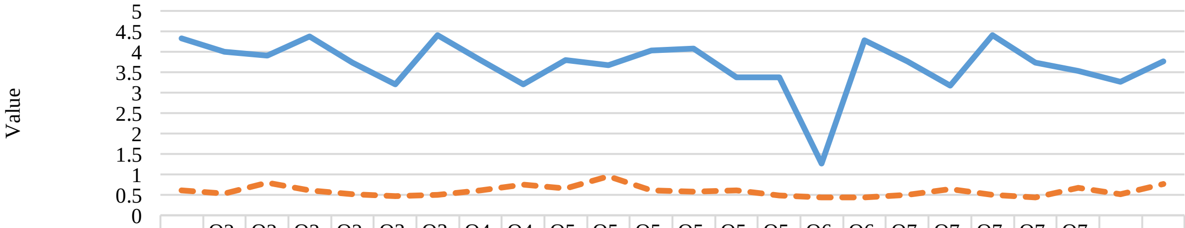


Figure 3: RII for EM and OSH Related Behavioural Issues

It can be observed that none of the issues were broadly accepted as “highly significant” by the respondents. Maximum value of recorded mean is 3.67 for I6 in OSH field and for the EM, it is recorded as 3.19 for issue I19. Respondents noted 10 issues that have got more than 3 as Mean. Only I2, I10, I11, and I15 were recorded as less than 3 for the Mean. STD of 8 issues out of 14 were recorded above 1 (STD > 1). Moreover, there are three (3) issues naming, I3, I11, and I15 were recorded above 0.9 STD (0.9 < STD < 1.0). Only STD of I18 was recorded less than 0.8 (STD < 0.8). It indicates all the issues except I3 are broadly dispersed. These facts clearly defines that the distribution of data is dispersed. Therefore, it can be understood all the issues are not equally significant for the garment factories.

STD value varies between 0.44 and 1.034. Lower STD defines that the data set is dispersed around the Mean. Therefore, the validity of the mean is comparatively higher. Mean of the data set vary from 1.27, to 4.47 on different factors. Nevertheless, respondent had noted 1.27 STD for the Q6.1. Therefore, respondents decided to reject Q6.1. Consequently, it was noted that answers of the respondents vary from “Not agreed” to the “Agreed” state. Aspects of each group were separately analysed. In fact word “employee” refers to the sewing machine operators. These facts are illustrated in Figure 4.

According to the qualitative data analysis, respondents highly noted to award many people instead of awarding only one employee (Q6.1). Rest of the aspects were approved by the respondents. However, some suggestions were made. It was suggested to, include a sector that relates to the production, improve monitoring mechanisms, more focus on low level people, improve awareness of employees, award more number of employees and introduce more negative score recovering methods.



	Q1	Q2.1	Q2.2	Q2.3	Q2.4	Q3.1	Q3.2	Q4.1	Q4.2	Q5.1	Q5.2	Q5.3	Q5.4	Q5.5	Q5.6	Q6.1	Q6.2	Q7.1	Q7.2	Q7.3	Q7.4	Q7.5	Q8	Q9
Mean	4.33	4	3.9	4.37	3.73	3.2	4.4	3.8	3.2	3.8	3.67	4.03	4.07	3.37	3.37	1.27	4.27	3.77	3.17	4.4	3.73	3.53	3.27	3.77
STD	0.61	0.53	0.8	0.61	0.52	0.48	0.5	0.61	0.76	0.66	0.96	0.61	0.58	0.61	0.49	0.45	0.45	0.5	0.65	0.5	0.45	0.68	0.52	0.77

Figure 4: Mean and STD for Aspects of the Computer Model

The concept of a computer model designed to change the attitudes and behaviours on OSH and EM activities can be effective as it forms a stage for the competitiveness in the working environment which will prove effective. However, many respondents have noted that this concept is innovative computer game was designed to improve the attitude of employees and then improve the behaviours relating to the OSH and EM. Each and every employee has to take a part in this computer game. Behavioural issues relating to OSH and EM of the employees are observed by the supervisors and marks are given based on their behaviours. This score decides the behaviour level. Each behaviour has got a unique value and similarly each level is assigned a unique weight. A character is assigned for each employee and it was assumed that employee maintain his character. Therefore, computer game defines that there is an addiction of employees and it result to change attitudes of the employees. Therefore, it is assumed that OSH and EM behavioural issues would be changed. Figure 5 illustrate the aspects of the computer game model.

ID No.	Aspects of Computer Model	ID No.	Aspects of Computer Model
Q1	Computer model as solution for EM and OSH activities	Q5.3	Weights scales for behaviours
		Q5.4	Weight scales for score levels
Q2	Characteristics of the computer model	Q5.5	Employee temporary out due to absenteeism
Q2.1	Game value	Q5.6	Score for a absent days
Q2.2	Game goal	Q6	Award mechanism of the computer model
Q2.3	Game fantasy	Q6.1	Award only one employee
Q2.4	Game mechanism	Q6.2	Monitory gifts
Q3	Supervision mechanism on employees	Q7	Addiction of employees to the computer model
Q3.1	Supervising on employees	Q7.1	Judgemental approach
Q3.2	Biasness of supervising	Q7.2	Attributional approach
Q4	Character and background of the computer model	Q7.3	Diffusion of innovative theory
Q4.1	Assigned character for employees	Q7.4	Motivational approach
Q4.2	Character change based on the user levels	Q7.5	Theory of planned behaviour
Q5	Scoring mechanism of the computer model	Q8	Suitability of the current computer model as a solution to the OSH and EM activities of sewing machine operating employees
Q5.1	Negative points for miss-behaviours		
Q5.2	Bad levels based on negative points		
Q5.3	Weights scales for behaviours	Q9	Aspiration to Implement computer model in factory

Figure 5: Mean and STD for Aspects of the Computer Model

Majority of respondents have noted that the proposed computer model in section 3 is acceptable. Many features of the computer model are recorded above 3.0 mean. Nevertheless, respondents have noted that this computer model will be successful in garment sector, but they highlighted that it is difficult to conclude an opinion before implementing it. However, majority of respondents noted that they are willing to implement the computer model.

5 SUMMARY

Attitudes of the people are vital for a better society. Proper OSH and EM behaviours related to the activities in Garment manufacturing industry is concerned as critical. Behaviours committed by sewing machine operators are concerned for this research. Behaviours can be changed by altering attitudes. Six approaches have been identified to alter the attitudes; Attribution approach, conditioning and modelling approach, judgemental approach, theory of planned behaviour, diffusion of innovative theory, motivation. Computer models can be used as solution to improve the attitudes and six approaches can be integrated with it.

Ten significant behavioural issues were identified. Six out of ten is related to the OSH and the rest is related to the EM. Most significant OSH related behaviour is, not wearing PPE by the employees. Similarly it is noted that poor sitting positions and removing of safety devices of machine are also significant issues. On the other hand, not switching off probe lights when leaving, and removing of compressed air tubes for other purposes were noted as most significant two issues related to the EM.

Developed computer model was model was accepted by the majority of respondents. Main features, score mechanism, characters were majorly accepted. However awarding only one employee was not accepted by the respondents. Finally, it can be concluded that developed model is acceptable but it can be further enhanced with the improvements.

6 REFERENCES

Abdoli, S. and Semere, T.D., 2014. Investigation on Machine Tools Energy Consumptions. World Academy of Science, Engineering and Technology, *International Science Index, Industrial and Manufacturing Engineering,* 1(6), 188.

Ajzen, I., 2015. Consumer attitudes and behavior: the theory of planned behavior applied to food consumption decisions. *Rivista Di EconomiaAgraria,* 70(2), 121-138.

Almén, L. and J. Larsson, T., 2014. Health and safety coordinators in building projects. *Built Environment Project and Asset Management,* 4(3), 251-263.

Bandara, A., 2010. One electrocuted, thirty injured. *Daily mirror*. [online] Available from: http://www.dailymirror.lk/article/one-electrocuted-thirty-injured-8614.html [Accessed 01 December. 2016].

Bang, M., Torstensson, C. and Katzeff, C., 2006. *The PowerHouse: A Persuasive Computer Game Designed to Raise Awareness of Domestic Energy Consumption. Persuasive Technology*, E1-E1.

Bashiri, F., 2014. Light Pollution and Its Effect on the Environment. *International Journal of Fundamental Physical Sciences,* 4(1), pp.8-12.

Board of Investment of Sri Lanka (BOI), (2011). General Guidelines for Factory Buildings. [online] 7-11. Available from: https://goo.gl/Wcywsa [Accessed 04 March 2017].

Calvin, S. and Joseph, B., 2006. Occupation Related Accidents in Selected Garment Industries in Bangalore City. *Indian Journal of Community Medicine,* 31(3), 150-152.

Chen, A., Lu, Y. and Wang, B., 2016. Enhancing perceived enjoyment in social games through social and gaming factors. *Information Technology and People,* 29(1), 99-119.

Chen, Y., Chen, P., Hwang, J., Korba, L., Song, R. and Yee, G., 2005. An analysis of online gaming crime characteristics. *Internet Research,* 15(3), 246-261.

Coon, D. and Mitterer, J., 2013. *Gateways to psychology.* 13th ed. Australia: Wadsworth Cengage Learning.

Dalia, D., El-Kawi, M., and Hassouna, M., 2014. Applying Energy Management in Textile Industry, Case Study: An Egyptian Textile Plant. *International Energy Journal*, 14(2), 87-94.

Darabnia, B. and Demichela, M., 2013. Maintenance an opportunity for energy saving. *Chemical Engineering Transactions,* 32, 259-264

Department of Census and Statistics [DCS], (2015). Computer Literacy Statistics – 2015. [online] Available from: http://goo.gl/0OtQkz [Accessed 01 December. 2016].

Dheerasinghe, R., 2003. Challenges, Prospects and Strategies for the Garment Industry in Sri Lanka. S*taff Studies,* 33(1), 33-70.

Dissanyake, C. and Fonseka, R.T. (2014). Blood on the factory floor – industrial accidents soar. *The Sunday Times.* [online] Available from: http://bit.ly/2eClK5r [Accessed 05 December. 2016].

Goetzel, R., Ozminkowski, R., Bowen, J. and Tabrizi, M., 2008. Employer integration of health promotion and health protection programs. *International Journal of Workplace Health Management*, 1(2), 109-122.

Guo, H., Li, H., Chan, G. and Skitmore, M., 2012. Using game technologies to improve the safety of construction plant operations. *Accident Analysis and Prevention,* 48, 204-213.

Huang, W., Johnson, T. and Han, S., 2013. Impact of online instructional game features on college students' perceived motivational support and cognitive investment: A structural equation modeling study. *The Internet and Higher Education*, 17, 58-68.

Islam, I. (2016). *Energy consumption determinants for apparel sewing operations: an approach to environmental sustainability*. Doctoral. Kansas state university.

Jayawickrama, A. and Thangavelu, S., 2017. ASEAN+1 FTAs and Global Value Chains in East Asia: The Case of the Textiles and Clothing Industry in Sri Lanka. In: c. Findlay, ed., *ASEAN+1 FTAs and Global Value Chains in East Asia*, [online] 232-274. Available from: https://goo.gl/ty05dF [Accessed 01 December. 2016].

Karuhanga, B., 2015. Evaluating implementation of strategic performance management practices in universities in Uganda. *Measuring Business Excellence*, 19(2), pp.42-56.

Kumar, R., 2012. *Research methodology*. 3rd ed. Los Angeles: SAGE.

Lardner, S., 2015. Effective reward ensures effective engagement. *Strategic HR Review*, 14(4), 131-134.

Lombardo, S., Vijitha de Silva, P., Lipscomb, H. and Østbye, T., 2012. Musculoskeletal symptoms among female garment factory workers in Sri Lanka. *International Journal of Occupational and Environmental Health*, 18(3), 210-219.

Martins, T., Carvalho, V., and Soares, F., 2016. Integrated Solution of a Back Office System for Serious Games Targeted at Physiotherapy. *International Journal of Computer Games Technology* 1(1), 1-11.

Mohamad, M. D. and Hussien Habib, M., 2013. Auditor independence, audit quality and the mandatory auditor rotation in Egypt. *Education, Business and Society: Contemporary Middle Eastern Issues,* 6(2), 116-144.

Muhwezi, L., Acai, J., and Otim, G., 2014. An Assessment of the Factors Causing Delays on Building Construction Projects in Uganda. *International Journal of Construction Engineering and Management*, 3(1), 13-23.

Orland, B., Ram, N., Lang, D., Houser, K., Kling, N. and Coccia, M., 2014. Saving energy in an office environment: *A serious game intervention. Energy and Buildings*, 74, 43-52.

Padmini, D. and Venmathi, A., 2012. Unsafe Work Environment in Garment Industries, Tirupur, India. *Journal of Environmental Research and Development*, 7(1A), 569-575.

Park, B. and Lee, K., 2011. Exploring the value of purchasing online game items. *Computers in Human Behavior,* 27(6), 2178-2185.

Pratheepkanth, P., 2016. Reward System and Its Impact on Employee Motivation in Commercial Bank of Sri Lanka Plc, In Jaffna District. *Global Journal of Management and Business Research,* 11(4), 84-92.

Primack, B., Carroll, M., McNamara, M., Klem, M., King, B., Rich, M., Chan, C. and Nayak, S., 2012. Role of Video Games in Improving Health-Related Outcomes. *American Journal of Preventive Medicine*, 42(6), 630-638.

Rieber, L. and Noah, D., 2008. Games, simulations, and visual metaphors in education: antagonism between enjoyment and learning. *Educational Media International,* 45(2), 77-92.

Rogers, E., 2003. *Diffusion of innovations.* 1st ed. New York: Free Press.

Samarasinghe, N., Ariadurai, S.A., and Perera, M.E.R., 2015. Facing the Future Challenges of the Sri Lankan Apparel Industry: An Approach based on Porter's Diamond Model for the Competitive Advantage of Nations. *Journal of Engineering and Technology of the Open University of Sri Lanka*, 3(1), 1-17.

Serinken, M., Turkcuer, I., Dagli, B., Karcioglu, O., Zencir, M. and Uyanik, E., 2012. Work-related injuries in textile industry workers in Turkey. *Turkish Journal of Trauma and Emergency Surgery,* 18(1), 31-36.

Shi, Y. and Shih, J., 2015. Game Factors and Game-Based Learning Design Model. *International Journal of Computer Games Technology,* (2015), pp.1-11.

Shook, C. and Bratianu, C., 2008. Entrepreneurial intent in a transitional economy: an application of the theory of planned behavior to Romanian students. *International Entrepreneurship and Management Journal*, 6(3), 231-247.

Sri Lanka Sustainable Energy Authority (SLSEA), 2009. *Code of practice for energy efficient buildings in Sri Lanka.* Democratic Socialist Republic of Sri Lanka.

Swartout, W. and van Lent, M., 2003. Making a game of system design. *Communications of the ACM*, 46(7), 32.

Tamborini, R. and Skalski, P., 2017. The role of presence in the experience of electronic games. In: Vorderer and J. Bryant, ed., *Playing Computer Games: Motives, Responses, and Consequences,* [online] 225-240. Available from: https://goo.gl/5d1YhO [Accessed 04 December. 2016].

Vanhala, E., Kasurinen, J. and Smolander, K., 2015. Evolution of computer game developer organizations. *Journal of Advances in Management Research,* 12(3), 268-291.

Yang, S., Shipworth, M., and Huebner, G., 2015. His, hers or both's? The role of male and female's attitudes in explaining their home energy use behaviours. *Energy and Buildings,* 96, 140-148.

CONSTRAINS IN INTEGRATING FACILITIES MANAGER IN THE PROJECT DEVELOPMENT PROCESS IN CONSTRUCTION INDUSTRY

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ABSTRACT

The role of a Facility Manager is to optimize the building performance and ensure smooth operations. The importance of having a facility manager in the development phase of construction projects has been recognised by a majority of the construction companies around the world. Sri Lankan construction sector is yet to recognize the full potential of the Facility Manager, especially in fine tuning a construction project and thus ensuring better operations later. The aim of this research was to identify the potential roles of a Facility Manager and constraints in integrating a Facility Manager in building project development process in Sri Lankan construction industry.

In order to achieve the objectives of this research 9 semi structured interviews were conducted among FM and non-FM professionals of the building construction sector and 4 expert interviews were conducted among experienced building construction professionals. Through the interviews, it was identified that Facility Managers have several potential roles in a construction project such as facilities consultant, facilities manager, facilities advisor, facilities supervisor, maintenance advisor and lighting planner. Moreover, several constraints such as limited authority, financial constraints, communication lapses, lack of resources, cost variations and knowledge gap etc. which have restricted the involvement of a FM were recognized through the interviews. Finally, the expert opinions were used to recognize how to integrate the FM in to construction projects by mitigating the constraints and how to utilize the FM knowledge and competencies for building project development process.

Keywords: *Building Construction; Construction Industry; Constraints; Facility Manager; Project Development Process.*

1. INTRODUCTION

Chodasova (2004) has described the project development process as a concept that comprises various processes starting with the project initiation, preparation, design, construction; proper space utilization and building operation. According to Brat (1996), project development process requires an integrated multi-disciplinary approach to have a better final output.

As to Barrett and Baldry (2003) building processes which includes designers, clients and end users are lacking the communication between the end users and the other group of designers and client. The lack of communication makes designers and clients to take decisions based on their experience than looking at the end user requirements. Barrett and Baldry (2003) further indicated that improper communication has affected the cost-effective nature, operability and the maintainability of the project.

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Even though various experts are involved in a project development process, some building defects can be identified. “The Building Research Establishment in England conducted a survey of building failure patterns and their implications and found that 58 percent of the defects have originated from faulty design” (Seeley, 1986).

Keaikitse (2012) states that the Building requires many limited natural resources to construction, operation and maintenance, thus making a larger impact in both direct and indirect ways to the environment. Therefore, the need of designing a simple and cost-effective maintenance of facilities are being highlighted throughout the life cycle of the facility including project conception phase, design phase, construction phase and post construction phases.

Alexander (2009) found that Facilities Management is the discipline responsible for “coordinating all efforts related to planning, designing and managing buildings before and after the construction”. In Sri Lanka facilities management is a budding profession and their role is mostly limited to operational and maintenance phase of a project. The facilities managers’ skills and competencies can bring many value additions to projects if they can involve in projects from the beginning.

There are many organizations and professional groups involved in project development in Sri Lankan construction industry such as Quantity Surveyors, Architects and Engineers etc. However, currently Facilities Managers are not involved in project development processes. In general, Facilities Managers are employed as maintenance or management executives after the construction. It directly helps to reduce the maintenance needs and help to manage the building in an efficient way. According to a study by Silva (2011), the involvement of Facility Manager in the early stage of buildings is important to ensure benefits as mentioned above.

Thus, the aim of this research was to identify the potential roles of a Facility Manager in the project development process and constraints in integrating a Facility Manager in project development process in Sri Lankan Construction industry. Accordingly, study initially identified the benefits of appointing a Facility Manager in project development process which was followed with examination of the current practice of Facilities Managers in project development process in Sri Lanka. Next presents the literature review on importance of facilities manager in project development process with special emphasis to construction industry.

2. LITERATURE REVIEW

Facility Managers are looking after the operations and the building management and thus they always have a direct contact with the facilities end users (Jensen, 2009). The communication with end user enables them to clearly identify the requirements of a facility and vast knowledge gathered through such experiences make them valuable in planning new facilities. Lehrer (2001) assert that the facility management profession has developed to some extent through demand led elements such as the need for cost reduction in the operation and maintenance of buildings.

Mohammed and Hassanain (2010) further argued on the direct involvement of Facility Manager in project development process exclaiming that it reduces the future problems which can be raised in maintenance as a Facility Manager has practical knowledge gained by performing different tasks during the operation stage of certain facilities. These can be used to identify significant design decisions which should be addressed in design phase as they affect the facilities maintainability. As per Ranawakage (2010) a facility can more efficiently provide its intended purpose of supporting the business, when a facility manager is there to look after the building.

Erdener (2003) states that a Facility Manager who is responsible for the maintenance management activities throughout the operational lifespan of the facility can make a greater impact on functionality enhancing, sustainability enhancing and the profitability enhancing and, moreover it can enhance the maintainability of projects. This view is supported by El-Haram and Agapiou (2002), who also insisted that a Facility Manager should be involved in project development process from design stage. Involvement of Facility Managers in project design directly impact on how buildings are designed, built, commissioned and refurbished and moreover it enables to take decisions which affects the efficiency and cost effectiveness of operation and maintenance of the building. Silva (2011) suggests that if a Facility Manager can be involved in the project development process in Sri Lanka; better high-rise buildings can be constructed considering the past due to the ability of the FM to incorporate knowledge gained through the operational phases of existing structures.

According to Larsson (2002) the design phase is initiated once the contract is signed by the developer. Architects provide some of the basic services beyond planning such as schematic and final design, preparation of construction documents and administration of the agreements. This is due to the gap between developer and builder which creates communication issues. This view is supported by Silva (2011) who suggests Facility Managers as the professionals with the ability to fill the gap between developer and builder. Kincaid (1994) further indicated the inclusion of a FM during project proposal preparation and construction will lower the operating costs and increase the efficiency of services during the operational phase. Moreover, Johnson *et al.* (2008) has indicated that although a project team includes number of professionals, a FM has more input in the project development phase.

According to Erdener (2003), current research and practice suggests that the role of the facility manager have no connection with programming and design phase and it only starts with the occupancy phase despite many effective decisions are being made which affect to the operation in the design phase. It is common that those design decisions are not addressing the advantages of the realistic user needs, requirement of operational and functional activities and issues of maintenance. This is mainly due to the usual impression that the expertise of the facility manager is considered by a majority of clients and professionals as operational in nature. Silva (as cited in Mohammed and Hassanain 2010) has suggested that a facility manager can design spaces on different uses of the building before its occupied, he can give suggestions on passive energy conservation and he can advise on passive practices of a good performing building which can be adopted in the designing phase.

Korsvold (2004) has indicated that the current approach of Facilities Manager in project development process is totally differing from theory. However, Silva (2011) states that Facility Managers are being neglected as potential professionals in the construction sector by the property developers in Sri Lanka.

3. RESEARCH METHODOLOGY

Data collection was mainly done through semi structured interviews and expert interviews. The main aim of the interview was to identify the current practice of integrating Facility Managers to the project development process in Sri Lanka. The interviews were carried out among Facilities Management professionals and Non-Facilities Management professionals. Furthermore, detailed information from the professionals who have high insight in aggregated and specific knowledge were obtained to recognize the current situation as well as recommend solutions to create a better future for the profession.

At the data collection stage, data relating to the current practices related to the role of Facilities manager in project development process were collected and the role of facilities managers in project development process was assessed using semi structured interviews.

Table 1 and 2 show the FM and Non-FM professionals interview profile and the experts profile respectively.

Table 1: FM and Non-FM Professionals Interview Profile

Interviewee code	Interviewee title	Interviewee experience
FM 1	Facilities Manager	10 years
NFM 1	Project Manager	9 years
NFM 2	Mechanical Engineer	5 years
FM 2	Facilities Engineer	5 years
NFM 3	Project Manager	10 years
NFM 4	Civil Engineer	11 years
FM 3	Facilities Manager	4 years
NFM 5	Project Manager	16 years
NFM 6	Electrical Engineer	8 years

Table 2: Experts Interview Profile

Expert code	Interviewee title	Interviewee experience
E1	Mechanical Engineer	15 years
E2	Project Manager	16 years
E3	Civil Engineer	10 years
E4	Facilities Manager	10 years

Interview analysis attempts to find similar inception or base ideas under same concepts rather than stating the actual words they have used. Therefore, as a data reduction method, code-based content analysis was used in this study to extract the most important concepts for reliable and comparable interpretation.

Experts selected for the interview had a minimum of ten years' experience in the construction industry. All the experts were involved in construction related project for the last two years which enabled them to have sufficient knowledge to provide a view on potential role for a FM in a construction project. The focus was to grab the opinions of FM and Non-FM professionals about the potential role that a FM could play in the project development process of a construction project.

4. RESEARCH FINDINGS

Based on the data collected, potential role of a FM in the project development process was analysed under different perspectives. The research findings were categorized under the following headings to discuss the probable role and constraints faced by a FM in the project development process as well as the remedies to overcome the challenges.

4.1. IMPORTANCE OF A FACILITIES MANAGER IN A PROJECT DEVELOPMENT PROCESS

Project development process is incorporated from planning stage to disposal of a construction. It is done by many professionals and experts, sometimes including or excluding a facilities manager. There is a fact that the most disciplines involved in project development process would not be doing work after completing the construction. Facilities Managers are the professionals who will manage a building after construction. Accordingly, a FM possesses the knowledge of building requirements which can be utilized to acquire number of benefits during the project development process. As per the views of the respondents' number of facts which describe the importance of having a FM in a project development process have been identified:

- Reduce operational and maintenance costs
- Ensure sustainable development
- Ensure standardized construction
- Maximize space utilization
- Reduce energy consumption

Majority of the respondents (92%) agreed with the fact that having a FM in the project development process would reduce operational and maintenance costs during the operational phase of the building. Out of the respondents 73% indicated that having a FM professional in the project development process would ensure sustainable project development. Majority of the Non-FM professionals indicated that FM is not essential in securing sustainable development. Majority of the respondents indicated that a FM would provide energy saving solutions in the long term operational process of the building. Apart from the above, FM was considered to be playing a vital role in several other aspects such as human resource handling and time management. Five factors mentioned above were recognized as key elements of having FM in a project development process.

4.2. CONTRIBUTION OF A FACILITIES MANAGER IN THE PROJECT DEVELOPMENT PROCESS

Multiple professionals involve in a construction process from the planning stage. In order to make a project more successful it is essential to get the service of the right professional at the right time. Through the study, it was recognized that the FM can involve in a project development process in different roles. As per the responses of the FM and non-FM professionals FM can contribute under the following roles in a project development process.

- Facilities Supervisor: Provide advices during the construction process about the user requirements which in latter stages will provide easy adoptability for the user.
- Facilities Consultant: Provide consultation to make the building sustainable, user friendly and increase the functionality during the construction process.
- Integrator: Work as the communicator between the user and the builder to make the project more versatile. Act as the project coordinator throughout the construction process and integrate the facility to suite the user.
- Maintenance Advisor: Provide an insight to the maintenance practices of the potential facility and thus build the structures with sufficient provisions for maintenance.
- Facilities Manager: Involve in the project from the beginning and gain a thorough insight to the building and its ailments to work through its life cycle.

All the respondents agreed that under the prevailing circumstances of the construction industry, adding a professional who will manage the facility after construction will be extremely useful. Respondents further indicated that contribution as a Facilities Consultant and Facilities Supervisor would have a significant impact to the project development process. Respondents further acknowledged the fact that construction industry has not identified this potential of a Facilities Manager due to several constraints.

4.3. CHALLENGES FACED BY FACILITIES MANAGERS IN THE PROJECT DEVELOPMENT PROCESS

Facilities Managers face several challenges in project development process. These challenges differ depending on the project size, location and the company. When considering about project development process various people may involve with different knowledge, experience and various disciplines. According to the view of the FM respondents, a FM has to face the following challenges during a project development process.

In most of the situations the Facilities Managers are being underestimated by their stakeholders. All the FM respondents identified this as a major issue which restricted the involvement of a FM in the project development process. Facilities Managers tend to focus more on the future costs which is likely to increase the present cost of a project. Therefore, the project stakeholders hesitated to accept the involvement of a FM in the project development process. According to the FM respondents in most of the situations FM has to work under the project manager or Engineers. As a result of that the FMs authority has been limited which is recognized as another major issue. No separate fund is allocated to Facilities Managers to do their design in project development process. Facilities Managers always work with other stakeholders with their allocated fund. Therefore, Facilities Managers always work under the financial constraints. As mentioned before number of different professionals involve in the project development process. Therefore, Facilities Managers are facing challenges to create the efficient communication between Facilities Managers and other professionals who are working in a project development process.

The field of Facilities Management is now occupied by various disciplines. According to the view of the FM respondents this has reduced the employability of the FM professionals in the project development process. According to the view of the FM respondents, FM professionals lacked in-depth knowledge about certain aspects. As a result of this knowledge gap FM professionals hesitate to take up a role in a project development process. All the respondents indicated that the lack of understanding about the FMs role by developer and the consultant has also resulted an issue in getting the FM involved in a project development process. Project developers' choice is recognized as the final choice in a construction project. When developer or owner thinks Facilities Managers are not needed in project development process for particular project, Facilities Managers will lose the chance to work in.

Based on the respondent views, identified challenges were ranked as follows:

- Stakeholders reluctance to hire a FM during the project development phase
- Lack of understanding about the FMs' potential role
- Limited authority FM has during the project development process
- Competition among similar professions in obtaining the position
- Lack of funds provided for the FM during the process

These challenges have restricted the FM becoming an active part of the project development phase. As a result, FM professionals, have also restrained from entering into the construction industry during this phase. FM respondents confirmed this by citing several industry examples and respondents who are involved in the construction industry confirmed the above findings.

4.4. REMEDIES TO OVERCOME THE CHALLENGES

It is evident through the interviews that challenges have restricted the significant contribution a FM can provide in the project development process. To identify the probable solutions for the aforementioned challenges several expert interviews were carried out. Experts provided viable solutions which would in long term improve the involvement of the FM in the project development process.

- Promoting Facilities Management

Most of the challenges FM professionals have faced is a result of the lack of awareness about the profession. Therefore, it is necessary to promote the profession within the Sri Lankan context. To eliminate this challenge a wide variety of actions were suggested by the experts. Most of them are marketing tools such as Exhibitions, Exposes, Meetings, Rallies, television programmes, newspaper articles, magazines, advertisements and websites. Experts further indicated that immediate actions should be taken to improve the awareness about the Facilities Management professionals. Furthermore, it is necessary to provide a clear idea about the job role of the FM and thereby eliminate the general practice of getting the FM involved in the project operational phase.

- Continuous practice and experience gaining

Lack of knowledge was also recognized as a major issue in getting the FM involved in the project development stage. According to the view of the experts it is necessary to keep on practising in the industry to improve the knowledge. Especially FMs should practice more in the construction industry and gain more experience to reduce the knowledge gap.

- Setting clearer objectives

When someone with more exposure of any other field than Facilities Management is involved, he might be weighing more to his own idea rather than aligning with the project objectives. One way to overcome this is focus more about achieving overall objectives of the project. Setting clearer objectives in a perception of a facilities manager is better. It will be more efficient to recruit a facilities manager who can carry out this workload more professionally.

- Authorize the FM

This is another significant challenge faced by the FMs when they work in the industry. FM respondents indicated that lack of authority is a major issue in making a considerable impact to the project development process. Allowing facilities manager in a position where he can go through others designs before the final approval and make suggestions and differences will be an answer to this problem.

5. CONCLUSIONS

Facilities management is not a well-established profession in Sri Lanka yet. This scenario suggests that there are plenty of gaps to be identified and must be full filled to establish facilities management. The research problem, the role of Facilities Manager in project development process is a slightly touched area. A very few literatures provide role of facilities management in project development process. When considering the unawareness of the Facilities Manager this may cause a huge draw back to the facilities management field in Sri Lanka.

This research has examined the impact of the facilities manager by elaborating the project development process and the role of facilities manager. The main aim of the project was to identify the potential roles a FM can play in the construction project development phase. Whilst achieving this aim, this research has also identified some of the key constraints that have restricted the FM being an integral part of the project and with the expert support remedies were identified to improve the involvement of FM professionals in the construction project development phase.

Throughout the literature survey it was clear that the field of facilities management is broad and continues to widen verities in the facilities management scope as different entities have different approach to the profession. To balance the research perspective, the viewpoints have been changed as facilities managers' point of view and non-facilities managers' point of view. The significant benefits suggest that the strategic and tactical management function of Facilities management can help to align the projects goals and resource with his professional skills.

A Facilities Manager can get sustainable development, make the construction meet the clients need with highest potential, maximize the space utilization and energy saving, minimize the operational and maintenance cost, eliminate the design errors of the project and implement local standards and regulations. Furthermore, a Facilities Manager can reduce expectation failures of clients and developers, negative impacts related to efficiency, productivity and sustainability, health and safety, and maintainability. The two different standpoints of Facilities Managers and non-Facilities Managers have been mostly same. They both suggest that there are gaps to be full filled in project development process and a Facilities Manager is able to fulfil them.

6. REFERENCES

Alexander, K., 2009, *Facilities management futures,* Manchester, UK: Euro FM Publication.

Barrett, P., and Baldry, D., 2003, *Facilities management: Towards Best Practice*, 2nd Ed., Oxford: Blackwell Publishing ltd.

Brat, J.M.H., 1996, Developments in the management of facilities at large corporations, *Facilities*, 14(5), 39–47.

Chodasova, Z., 2004, Facility management in development process, *Economics and business management*, 2(6), 52-60.

El-Haram, M., and Agapiou, A., 2002, The role of facility managers in new procurement routes, *Journal of Quality in Maintenance Engineering*, 8(2), 124-134.

Erdener, E., 2003, Linking programming and design with facilities management, *Journal of Performance of Constructed Facilities*, 17(2), 4-8.

Jensen, P., 2009, Design integration of facilities management, *Architectural Engineering and Design Management*, 5(3), 124-135.

Johnson, G., Scholes, K. and Whittington, R., 2008, *Exploring the Corporate Strategy*, UK: Prentice Hall.

Keaikitse, T., 2012, *Evaluating the facility manager's role in project design*, University of the Witwatersrand, Johannesburg.

Kincaid, D., 1994, Integrated facility management, *Facilities*, 12(8), 20 23.

Korsvold, T, 2004, *Generic process for facilities development*, Trondheim, Norway: Grassroots club administration.

Larsson, N., 2002, The Integrated Design Process, *Report on a national workshop*, [online] Mortgage and Housing Corporation, Toronto: Canada. Available from: http://www.waterfrontoronto.ca/dbdocs//4561b17f1ccf1.pdf [Accessed 15 March 2014]

Lehrer, D., 2001, Sustainable Design, *Facility Design and Management Handbook*, New York: McGraw-Hill.

Mohammed, M., and Hassanain, M., 2010, *Towards improvement in facilities operation and maintenance through feedback to the design team,* Dhahran: King Fahd University of Petroleum and Minerals, Architectural Engineering Department. Available from: http://www.tbher.org/index.php/tbher/article/download/28/29 [Accessed 20 March 2014]

Ranawakage, R.S., 2010, *Factors affected decision making on in-housing and out-sourcing of commercial building maintenances* (Unpublished B.Sc. Dissertation), University of Moratuwa, Sri Lanka.

Seeley, I., 1986, *Building technology*, London, UK: Macmillan Education.

Silva, D., 2011, Promoting the facilities management profession in the project development phase of high-rise buildings in Sri Lanka, *Built Environment Sri Lanka*, 9(1-2), 37-38.

CONSTRUCTION INDUSTRY INVESTMENT CHALLENGES: BARRIERS FOR SME EXPANSION

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ABSTRACT

This research concentrates upon the requirements for expanding Small and Medium (SME) contractors into the level of large scale contractors and barriers for such. Adequate assets are a key requirement for succeeding in construction business. Construction companies have many physical and impalpable assets. Given the SMEs fulfil required asset levels, with proper management, it is possible for SMEs to expand over time and achieve the goal of becoming large scale organisations. However, improving the grades should not focus only upon turnover, yet various other resource and management requirements need to be met.

In order to identify the exact requirements of SME to large scale conversion, necessary asset level changes and barriers for such conversions were required to be analysed. A quantitative approach was taken in collecting field data and the data were collected through a questionnaire survey. Contracting organisations were considered as the unit of analysis and data were collected from 205 units with a response rate of 76%.

The research reveals the necessity of improving annual turnover, P&E, and staff assets of SMEs in reaching the large-scale organisation level. In doing so; management issues, lack of finance and motivation, and employees with insufficient knowledge and skills are the critical internal challenges. The external barriers were identified as: high cost of capital, inadequate financial structure, changes in the government policies and the political unrest, and lack of information. Thereby overcoming the identified barriers will enable SME expansion, which will increase construction industry investment complementing the economic development.

Keywords: *Asset levels; Barriers; Construction industry; Investment; SME.*

1. INTRODUCTION

The construction business is one of the fastest mounting industries around the globe (Beesley and Caron, 2012). Consequently, technological, political, economic and social facets as well as their interrelatedness have to be considered within a study of the construction sector's future achievements (Bourdeau, 1999).

In construction industry, stakeholders include a wide range of entities that directly or indirectly can provide support or resistance to the accomplishment of project objectives (Walker and Derek, 2000). However, contractors are being identified as one the main stakeholders being an important investor to the construction business. In Sri Lanka, Construction Industry Development Authority (CIDA) offers national registration and grading schemes for construction contractors. These grading schemes help to determine the general ability of the contractors (ICTAD, 2013).

To sustain the present market conditions, Small and Medium Enterprises (SME) need to expand their companies. Love and Irani (2004) found the main competitive power for SMEs within the construction industry depend on the role of the owner or manager of the company, investments in intellectual capital, investments in information and communication technology, and the skill to adapt to change. However, the greater deviation in continuity, profitability, and growth of SMEs compared to larger firms accounts for special problems related to financing. Such financing concerns differ considerably between those which grow slowly and those which

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grow rapidly, as well as between exiting and new firms (Crichton, 2006). The expansion of private equity markets, including informal markets, has greatly improved the access to venture capital fore start-ups and SMEs, but considerable differences remain among countries. In such background, SME expansion will necessarily enhance the investments in construction industry vice versa.

2. LITERATURE REVIEW

Development of SME sector is foreseen contributing to transform of lagging regions into emerging regions in terms of prosperity. Even SMEs are the most defenceless sector inside a country's economy, it directly affect the economic performances (Crichton, 2006). Romero-Martinez *et al*. (2010) state SME sector as one of the main motor behind a country's economic growth. SME sector has been identified as an essential strategic sector, in the overall policy objectives of the Government of Sri Lanka (GOSL). Accordingly, in local context, SME sector is seen as a driver of transformation for inclusive economic growth, regional development, employment generation and poverty reduction.

SME is a very heterogeneous group. Statistical measures for size and standard of SMEs varies along countries. Yet, typically, such measures are based on number of employees, and value of sales and assets. The commonly used variable is the number of employees as due to its ease of collection (Manley, 2006). Hence, the development strategies for SMEs will be importantly country and context specific. Each country will have its own issues and opportunities for change. Moreover, resources available for implementation will vary along countries, therefore the results achieved will also may vary (Bannock, 2005). Hence, the emphasis should first need to be towards the identification of the current asset portfolios of construction industry SMEs.

2.1. ASSETS PORTFOLIOS OF CONSTRUCTION ORGANISATIONS

Assets are used by companies to make benefits (The Complete Guide to Portfolio Construction and Management Snopek, 2013). The main objectives of having assets are to get the best return from the investments and to achieve goals as of organisational strategic plans. Assets, therefore, are a key in succeeding construction business. Construction organisations have many physical and impalpable assets. Construction accounting comprises of two main groups of accounts on assets as; tangible and non-tangible. Tangible assets have a definite physical form (The Complete Guide to Portfolio Construction and Management Snopek, 2013). Tangible assets can be classified as non-current tangible and current tangible assets. Non-physical assets, which are important for the business are called as intangible assets (Jaunzens, 2001).

In considering the development of firms, small firm growth theorists (Davidsson *et al*., 2005) refer growth as the change in an organisation's size, which is a multidimensional phenomenon that necessarily happens over time. In the analysis of firm growth from the change- in-size perspective, growth has been measured with a range of different indicators in the literature; the most frequently suggested being sales, revenue, employment, assets, physical output, market share and profits (Ardishvili *et al*., 1998; Delmar, 1997; Weinzimmer *et al*., 1998; Wiklund, 1998).

Accordingly, in the context of this study, multiple indicators i.e. turnover, e.g. Plants and Equipment (PandE) assets, and permanent skilled employees were used to measure SME growth performance in construction sector. These indicators are chosen also considering the South African Construction Industry Development Board (CIDB)'s indicators of company growth and development. Whereas, financial capability, works capability, and number of registered skilled professionals in a firm are the main necessities for progressing through CIDB contractor grading system in South African construction industry.

2.2. RELATIONSHIP BETWEEN ORGANISATION ASSETS AND CONTRACTOR GRADING

The service of grading given by an independent body's opinion based on the quality of the entity graded, enhances the lenders' confidence upon the construction service providers (IMACS, 2011). Besides, grading benefit participants by highlighting their competencies and helping them stand out in a crowd (Balachandra, 2014). Opportunities for new comers to the market are generated by contractor grading systems and it greatly helps to clients in identifying proper contractors for their projects. Hence, in Sri Lankan construction industry, there is a unique grading methodology developed by CIDA urbanised for the purpose.

CIDA as the government apex body in Sri Lanka to regulate construction industry implements a process of grading construction contractors. For assessing capabilities of prospective contractors, there is a screening process in registration and grading. The process facilitates determining contractors' general ability to undertake different types and sizes of projects without placing preference to any specific contractor. Financial capability, technical ability with staff and PandE, and the experience gained in relevant fields will be evaluated in registration and grading (CIDA, 2015). It is observable that the number of contractors registered under lower grades with financial strength limited to SL Rs. 1.0 M to SL Rs. 2.0 M is comparatively high (ICTAD, 2013). According to several industry experts, poor access to sources of funding is the key reason for a majority of the contractors to remain below the limitations of higher grades (Balachandra, 2014).

2.3. CHALLENGES AND OPPORTUNITIES FOR SME EXPANSION

Developing a new organisation and organising its development are viewed as a process of carrying out organisational change, with external and internal elements. However, the development and growth of the SME sector inside the construction industry is hindered by various barriers. Barriers to change can originate from a range of factors in an organisation. Such barriers, therefore, can be classified as internal barriers and external barriers (Davidsson *et al.*, 2005).

Common internal barriers were identified in the literature as; management issue, organization regulation, lack of employers, inefficient staff, employees with insufficient knowledge and skill (Baron and Shane, 2007), lack of financing (Olutunla and Obamuyi, 2008), lack of motivation (Schwartz and Hornych, 2010), poor book keeping (Tushabomwe-Kazooba, 2006), inexperience in the field of business (Omerzel and Antonic, 2008), lack of market research (Mbonyane and Ladzani, 2010), and weak institutional capacity (Kayanula and Quartey, 2000).

Further, the external barriers were identified as; legal barriers (Zahra and Ellor, 1993), inadequate financial structure (Kayanula and Quartey, 2000), firm regulations, trade regulation, tax regulations, changing government policies (IPS, 2002), corruption (Chandanie *et al.*, 2004), labour regulation (Urban and Naidoo, 2012), cost of capital (Thalgodapitiya and Dakshitha, 2008) and keen competition for limited capital (Zahra and Ellor, 1993) as per theory.

2.4. OBJECTIVES FOR THE SUCCESS OF SME SECTOR

Profitability, survival and growth are the greater variance of in terms of challenges for SMEs compared to larger firms, since they accounts for special problems in financing. Hence, the SME sector of the construction industry must have a vision and series of strategies for development that encourages stability, international competitiveness and capacity enhancement. The expansion of private equity markets, including informal markets has greatly improved the access to venture capital for SMEs, yet considerable variations remain amongst countries (Mbonyane and Ladzani, 2010). SMEs, therefore, should need to be managed in a personalised way, free from outside control in taking principal decisions (Burns, 1989).

3. RESEARCH METHODOLOGY

The research was initiated with a literature synthesis analysing the asset levels of the organisations allowing to classification of organisations based on the asset levels they possessed. Accordingly, the organisations were categorised into three as small (C7 and above), medium (C2 to C7) and large (below C3), following CIDA grading system. Basically, CIDA grading is based on the level of assets possessed by the companies. Further, the barriers faced by each organisation category; small and medium were investigated. A survey approach was adopted in order to identify the asset levels and critical barriers for organisations. Questionnaire survey was carried out by collecting data from 205 organisations including 100 small scale contractors, 80 medium scale contractors and 25 large scale contractors with an overall response rate of 76%. Weighted mean was calculated in order to find the critical barriers for the each organisation category.

4. RESEARCH FINDINGS AND ANALYSIS

It is evident that the asset level of an organisation has a deep impact upon the grading of the organisation. Hence, the asset levels possessed by the sampled organisations were analysed based on; the type of projects involved, annual turnover, number of projects that have been carried out in the last two years and the details of the PandE, and the management staff.

4.1. *Analysis on the Asset Levels of the Organisations: Project Types Carried Out*

There are five categories of projects as identified by CIDA. However, not all the contracting organisations undertake all types of projects. In Figure 1, it is visible that all the contracting organisations carry out building projects, while the larger organisations perform all kinds of projects. Bridge projects are only handled by large scale organisations. Medium scale contractors involve in highway and water supply and drainage projects in par with large scale organisations.

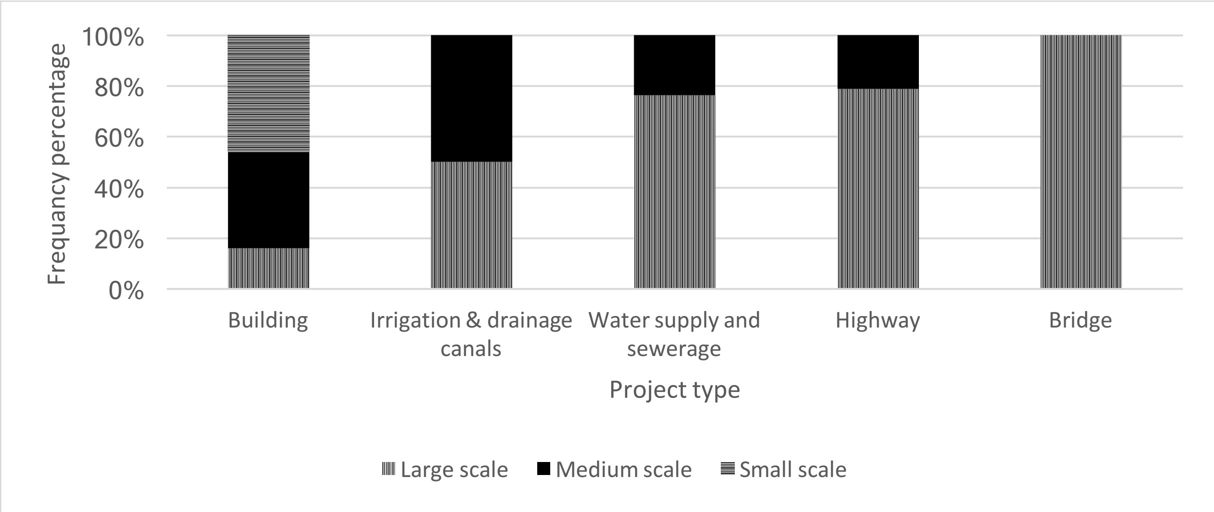

Figure 1: Project Types Carried Out Against Organisation Scale

It shows that the medium and the large organisations are only involved with different types of projects, where small contractors are limited to the building projects alone. Moreover, only a very few medium scale contractors undertake other types of projects.

4.2. *Analysis on the Asset Levels of the Organisations: Annual Turn-over*

The annual turnover against the scale of the three organisation categories are displayed in Figure 2.

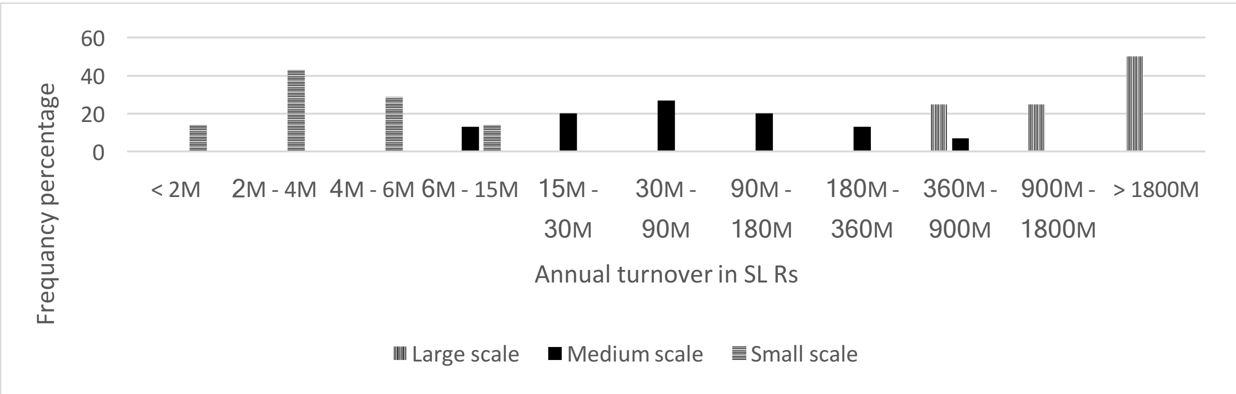

Figure 2: Annual Turnover Against Organisation Scale

It is visible that higher the grade, more the turnover. The small organisations have been limited to a turnover very much less than 15 million Sri Lankan Rupees (SL Rs.). As per CIDA, the annual turnover for the large organisations are required to be more than SL Rs. 360M. Similarly, medium organisations should possess annual turnover within SL Rs. 6M to 360M. The rest of the organisations below such levels are considered as small organisations.

As per Figure 2, organisations which are in the upper border of the medium level organisations, that is C2, accomplishes the requirement of turnover for large scale organisations of SL Rs. 360M. However, the percentage is not a considerable amount since only 40% of the C2 organisations have achieved such feat. Similarly, 10% of the C7 organisations have achieved similar feat by entering into the requirements of medium scale organisations. Hence, it is quite visible that the organisations in the upper border of the medium and the small organisations are trying to achieve a stable point in the annual turnover for the next league.

4.3. *Analysis on the Asset Levels of the Organisations: Range of Project Values Completed in Last Two Years*

Number of projects and its value is a good measure to compare the current status of the contracting organisations in the construction industry. Since the sample sizes vary to one another, the average number of the projects were considered for each grade. Results are quite similar to the pattern of the results for annual turnover since it has a direct connection over the annual turnover. Larger the organisation, larger projects in terms of value has been handled. However, the medium scale organisations tend to handle larger projects as well. Figure 3 shows that majority of small organisations carrying out the projects, which falls under the category of SL Rs. 2M to 5M.

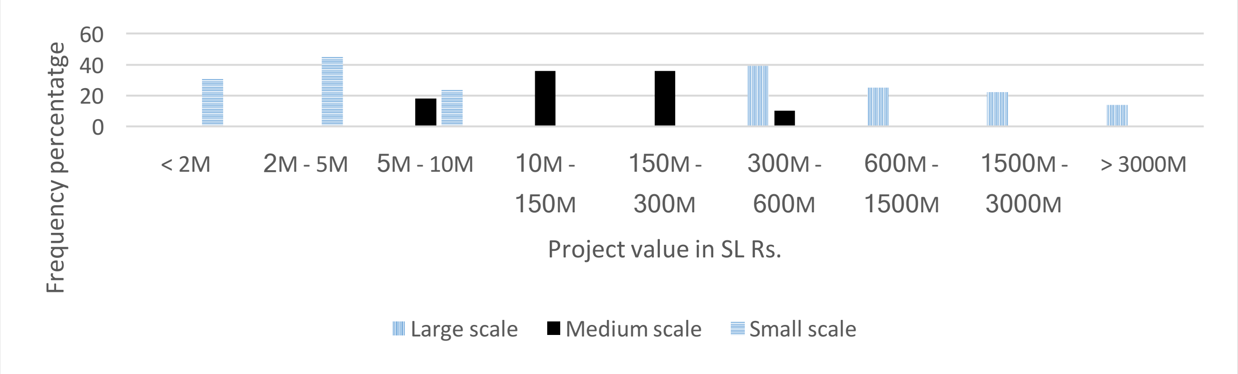

Figure 3: Project Values Against Organisation Scale

Similarly, the medium scale organisations undertake projects mostly between SL Rs.10M to 150M and SL Rs.150M to 300M. However, large organisations perform the projects under the categories according to their strength as per CIDA guidance. According to the CIDA guidelines, the upper border for the small organisations stays as at SL Rs.10M. Hence, small organisations perform the projects in their allocated range. Similarly, the medium organisations perform the works that falls under their range. However, the lower limits have not been a barrier in obtaining low value projects. Large organisations perform the works which fall lesser to their limits, which fall under the category of medium scale organisations. Similarly, the medium scale organisations perform the work below their allocated range. That is from the range of the small scale contractors, which is a problematic situation for SMEs in obtaining projects.

4.4. *Analysis on the Asset Levels of the Organisations: Construction Plants and Equipment*

Construction PandE as assets are one of the key possessions of an organisation. Figure 4 clearly displays that the small organisations lack in the construction PandE and related assets. However, medium and the large organisations possess almost all the PandE required for construction work. Hence, there will be no issues with the construction PandE as an assets requirement for the medium organisation in expanding into a large scale organisation. However, this will be a severe barrier for the small organisations, as it portrayed in percentages.

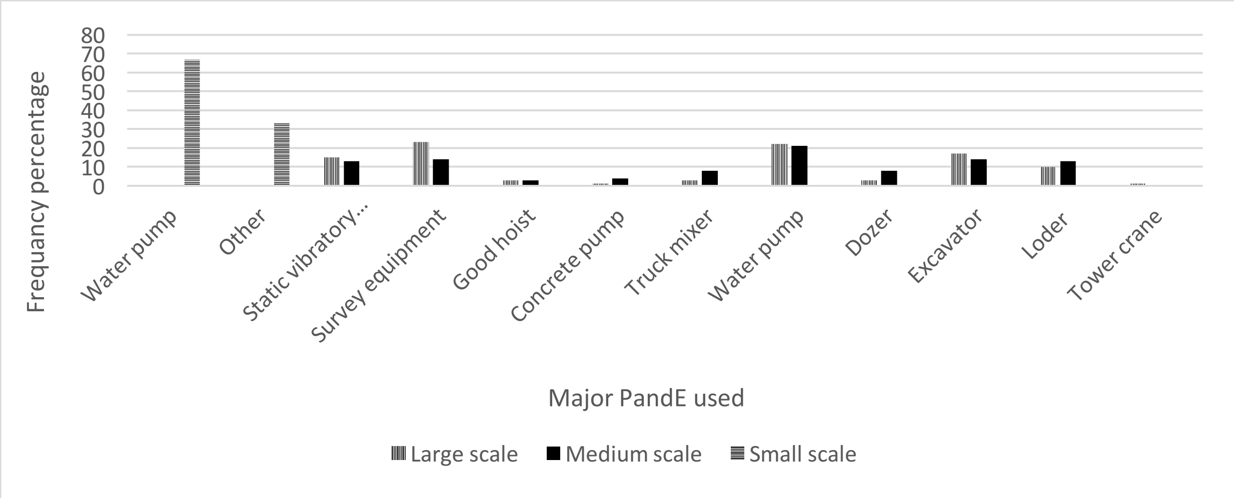

Figure 4: Plant and Equipment Against Organisation Scale

Hence, the number of required equipment may vary by large amounts for small scale organisations in moving into the medium scale organisation level.

4.5. *ANALYSIS ON THE ASSET LEVELS OF THE ORGANISATIONS: MANAGEMENT STAFF*

The construction management staff available at each organisation level has been considered for the analysis. The percentage composition of the staff within the researched sample is shown in Figure 5.

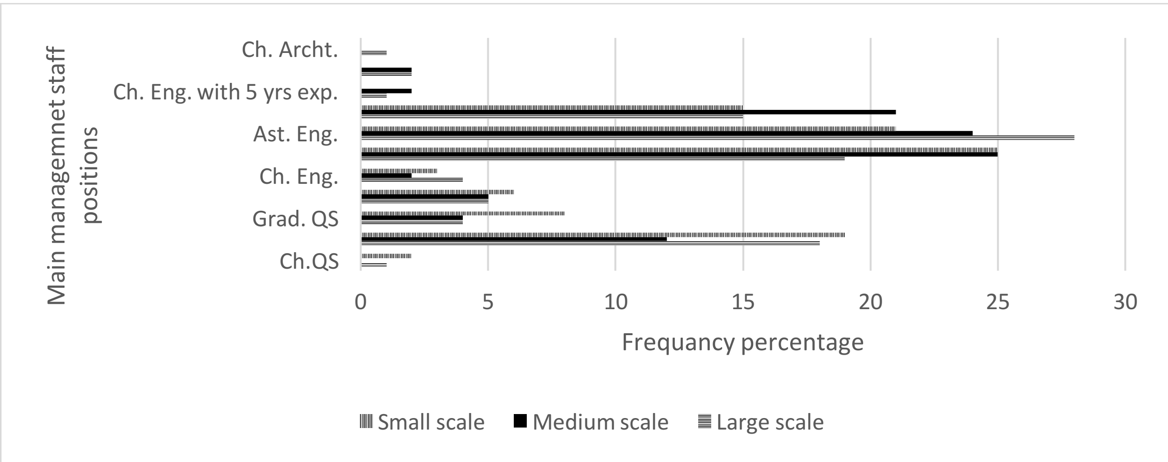

Figure 5: Management Staff Composition Against Organisation Scale

It was revealed that, small contracting organisations do not have highly qualified staff, in general. There are no considerable numbers of experienced chartered professionals at the small-scale organisations. In fact, chartered and qualified categories of professionals were only available with large contracting organisations and medium scale contracting organisations.

Small organisations only possess minimum requirement of the staff. However, compared to architects or quantity surveyors, more qualified engineers have been found in any organisation. Composition of the less qualified staff including assistant engineers, incorporate engineers, and assistant quantity surveyors are of almost same in percentage amongst scales. Yet, highly qualified professionals make the difference between organisations. As per CIDA requirements, to move from small scale to medium and large scale, highly qualified professionals in the staff is a prerequisite, where in the sample of large organisations possess the highly qualified professionals, while small scale organisations do not possess such qualified staff.

Therefore, analysed various assets levels of the organisations urge the need of improving SMEs in terms of assets to expand the organisations. The paper hereon presents the barriers for such expansions.

4.6. *ANALYSIS OF THE BARRIERS FACED BY SMES*

The research identified the critical barriers faced by SME contractors in expanding the organisations. Moreover, the internal barriers and the external barriers were analysed separately for each small and medium organisations.

- **Internal barriers for small scale contractors**

Table 1 provides the internal barriers identified though the literature survey for the small scale contractors as ranked by the respondents considering the severity.

Table 1: Internal Barriers for Small Scale Contractors

Code	Internal Barriers	Mean	Rank
IB 1	Management Issues	4.309	1
IB 6	Lack of Financing	4.259	2
IB 7	Lack of Motivation	3.148	3
IB 10	Lack of Market Research	3.148	4
IB 5	Employees with Insufficient Knowledge and Skill	2.679	5
IB 4	Inefficient Staff	2.506	6
IB 9	Inexperience in the Field of Business	2.383	7
IB 11	Weak Institutional Capacity	2.370	8
IB 2	Organisation Regulation	1.938	9
IB 8	Poor Book Keeping	1.938	10
IB 3	Lack of Employers	1.815	11

Accordingly, management issues, lack of financing, lack of motivation, and lack of market research were identified as the most critical internal barriers for the small-scale contractors in expanding into a medium scale organisational level.

- **External barriers for small scale contractors**

Table 2 shows the external barriers faced by the small-scale organisations.

Table 2: External Barriers for Small Scale Contractors

Code	External Barriers	Mean	Rank
RB 9	Cost of Capital	4.148	1
TB1	Lack of Information	4.061	2
RB1	Inadequate Financial Structure	4.012	3
RB 2	Firm Regulations	3.712	4
SB2	Lack of Effective Support	3.469	5
RB 8	Political Unrest	3.185	6
RB 7	Labour Regulation	3.123	7
TB2	Technical Knowledge	3.062	8
RB 5	Changing Government Policies	2.901	9
SB3	Market Research Information	2.901	9
RB 10	Competition for Limited Capital	2.79	11
RB 4	Tax Regulations	2.445	12
SB1	Unfriendly Environment	1.938	13
RB 3	Trade Regulation	1.852	14
RB 6	Corruption	1.223	15

Therefore, cost of capital, lack of information, inadequate financial structure, firm regulations, lack of effective support, political unrest, labour regulations, and lack of technical knowledge were identified as the most critical external barrier for the expansion of small scale contracting organisations.

- **Internal barriers for medium scale contractors**

Similar to the internal barriers for the small-scale organisations, internal barriers of medium scale organisations were analysed using weighted mean. The findings are presented in Table 3.

Table 3: Internal Barriers for Medium Scale Contractors

Code	Internal Barriers	Mean	Rank
IB 1	Management Issue	3.724	1
IB 4	Inefficient Staff	3.517	2
IB 3	Lack of Employers	3.328	3
IB 5	Employees with Insufficient Knowledge and Skill	3.310	4
IB 6	Lack of Financing	3.207	5
IB 7	Lack of Motivation	2.966	6
IB 2	Organisation Regulation	2.948	7
IB 8	Poor Book Keeping	2.862	8
IB 9	Inexperience in the Field of business	2.793	9
IB 10	Lack of market research	2.552	10
IB 11	Weak Institutional Capacity	2.241	11

Among the eleven barriers, the most critical internal barriers for medium scale contractors are; management issues, inefficient staff, lack of employees, employees with insufficient knowledge and skill, and lack of financing.

Therefore, it is evident that, management issues and lack of financing are commonly disturbing the expansion of the SME sector in the construction industry as internal barriers.

- **External barriers of medium scale contractors**

External barriers to be faced by the medium scale contracting organisations in expanding into large scale are presented in Table 4 in the order of severity.

Table 4: External Barriers for Medium Scale Contractors

Code	External Barriers	Mean	Rank
TB 2	Technical Knowledge	3.569	1
RB 4	Tax Regulations	3.552	2
RB 6	Corruption	3.397	3
RB 8	Political unrest	3.379	4
RB1	Inadequate Financial Structure	3.224	5
RB 3	Tread Regulations	3.103	6
SB3	Market Research Information	3.052	7
RB 5	Changing Government Polices	3.034	8
TB1	Lack of Information	3.034	9
RB 2	Firm Regulations	3.017	10
RB 10	Keen Competition for Limited Capital	2.966	11
RB 7	Labour Regulation	2.379	12
SB 1	Competition Unfriendly Environment	2.224	13
RB 9	Cost of Capital	2.000	14
SB2	Lack of Effective Support	1.379	15

Accordingly, ten factors were identified as critical external barriers among the 15 factors analysed. They are; technical knowledge, tax regulations, corruption, political unrest, inadequate financial structure, trade regulations, market research information, changing government policies, lack of information, and firm regulations.

Therefore, lack of information, inadequate financial structure, firm regulations, political unrest, and technical knowledge are the common external barriers for the SME expansion in construction industry.

Considering the asset level analysis, in overcoming the barriers for SME expansion, for a small contracting organisation, firstly, it would be required to establish the organisation in terms of vision, mission, management and staff. In doing so, building up the team spirit is vital and it would require extra efforts in stabilising the organisations. The establishment of a small scale organisation structure will need creating a business hierarchy to increase the efficiency and effectiveness of the business operations. Further, small scale contractors will need to give more attention to the social projects to gain good name in the society, which will help to raise their demands gradually. Further, it is required to strictly follow the government regulations to survive in the industry and to get incentives from government.

Similarly, medium scale contractors have to incorporate innovations to their projects. Moreover, proper documentations will help to develop the organisation in various ways. A solid top management system is required to be established to achieve the organisation goals in a shorter period, efficiently. Firm top management need to provide opportunities to grow and learn, and let the employees know there contribution for advancement of the company. Encouraging goal setting and letting employees contribute in such attempts also are important. Accordingly, the management should recognise and reward good work to promote best practices, which are necessary in advancing construction business.

5. CONCLUSIONS

This study analysed the barriers for expansion of small and medium contracting organisations in Sri Lanka. In grading the organisations, categories were identified as; large, medium and small in an asset perspective following CIDA grading criteria. As per the study, the SME contractors are almost limited to building construction work at the moment. However, the annual turnover of the medium and small contractors in higher grades are comparatively high, indicating positive financial capacities, which are necessary for expansions. Resultantly, the SMEs are currently involved in projects of high value. However, lower limits for project values as approved by CIDA does not evade large organisations obtaining small projects, reducing the business opportunities for SMEs. In terms of PandE assets, medium scale organisations are coping well, while small scale contractors need major improvement. Moreover, level of management staff available at SMEs are well below the requirements. Hence, it will be essential for SMEs to obtain lacking assets in expanding into large scale establishments. The critical barriers in doing so are; management issues, lack of finance and information, inadequate financial structure, firm regulations, political unrest, and lack of technical knowledge. Therefore, the interested SMEs should need to take necessary measures to overcome such barriers in order to continue with organisation expansions.

6. REFERENCES

Ardishvili, A., Cardozo, S., Harmon, S. and Vadakat, s., 1998. Towards a theory of new venture growth. In *Babson Entrepreneurship Research Conference*. Ghent, Belgium

Beckett, M., Drazin, S., finlay , d., Smith, H., Martin, N., Neathey, R., Wynniatt, M. (2009, October). *Performance of PFI Construction.* Retrieved august 30, 2016, from National Audit Office: https://www.nao.org.uk/wp-content/uploads/2009/10/2009_performance_pfi_construction.pdf

Acuna, M. I. (2000). . *Reducing time in the construction of high rise buildings* . Doctoral dissertation, Massachusetts Institute of Technology.

Ahn, H. Y., Pearce, R. A., & Wang, Y. (2013). Drivers and barriers of sustainable design and construction: The perception of green building g. *International Journal of Sustainable Building Technology and Urban Development, 4*(1), 35-45. doi:http://dx.doi.org/10.1080/2093761X.2012.759887

Ali, A. M. (2008). *Private Finance Initiatives as a part of the 9th Malaysian plan.* Kuala Lumpur: Azmi & Associates.

Allianz-Global-Corporate&Specialty. (2014). *Supertall Buildings Construction risk assessment in the 21st century.* Jonathan Tilburn, London: Allianz Global Corporate & Specialty.

Alshanbar, H. (2014). *Project Coordination Using Cloud-Based BIM Computing in Education.* Washinton: The building SMART alliance.

Arivazhagan, B. (2014). Automatic plastering machine. *Advanced Research in Electronics, Communication & Instrumentation Engineering and Development, 2*(2), 29-35.

Assaf, S., & Al-Hejji. (2006). Causes of delay in large cinstruction projects. *International Journal of Project Management, 24*(4), 349-357. doi:10.1016/J.ijproman.2005.11010

Asset Diversification. (2016). *Portfolio Construction and Analytics Fabozzi/Portfolio*, 202-231.

Balachandra , H. (2014). sri lanka country report. *The 20th Asia Construct Conference* (p. 76). Hong Kong: Institute for Construction Training and Development.

Beesley, & Caron. (2012, January 4). How to start a small construction or general contracting business. *Contractor Refference Guide*, p. 2.

Benmansour, C., & Hogg, K. (2-4 September 2002). An investigation into the barriers to innovation and their relevance within the construction sector. In D. Greenwood (Ed.), *18th Annual ARCOM Conference. 2.* Northumbria: University of Northumbria.

Bock, T. (1998). *Automation and Robotics in Building Construction.* Munich,Germany: technische University.

Bourdeau, L. (1999). Sustainable development and the future of construction: A comparison of visions from various countries. *Building Research and Information, 27*(6), 354-366.

Brent, S., & Vikki, B. (1994). Indoor air quality and textiles: An emerging issue. *American Dyestuff Reporter, 1*(1), 36-47. doi:infohouse.p2ric.org/ref/03/02906.pdf

Chen, J., Wang, J., & Jin, W.-l. (2016). Study of magnetically driven concrete. *Construction and Building Materials, 121*(1), 53-59.

Choi, Y., Kim, D. C., Kim, S. S., NAm, M. S., & Kim, T. H. (2013). Implementation of noise-free and vibration-free PHC screw piles on the basis of full-scale tests. *Journal of Construction Engineering and Management, 139*(8), 960-967.

Construction Industry in Sri Lanka. (2011). *Construction Industry in Sri Lanka.* Colombo: ICRA Lanka and IMaCS.

Corcoran , J., Zahnow , R., & Higgs , G. (2016). Using routine activity theory to inform a conceptual understanding of the geography of fire events. *Geoforum, 75*, 180–185.

Creswell, J. W. (2014). *Research design : qualitative, quantitative, and mixed methods approaches.* (4, Ed.) New Delhi, India: SAGE Publications India Pvt. Ltd.

Crichton, D. (2006). *Climate change and its effects on small businesses in the UK.* London: AXA Insurance UK.

Dahlin, T., & Yngvesson, M. (2014). *Construction Methodology of Tubed Mega Frame Structures in High Rise Buildings.* Stockholm, Sweden: Master Thesis in Concrete Structures, Royal Institute of Technology.

Denagama, J., & Hadiwattege, C. (2013). *Development Supportive Novel Trends and Practices for Construction Sector.* Colombo: Department of Building Economics, University of Moratuwa, sri Lanka.

Department of Project Management and Monitoring. (2016, January). *Development Performance - Mid Year Review 2015.* Retrieved August 31, 2016, from Integrated National Development Information System: http://www.pmm.gov.lk/resources/Development_Performance_YearEnd_2015.pdf

DiNapoli, T. (2013). *Private Financing of Public Infrastructure:Risks and Options for New York State.*

Doosan heavy industries & construction buys enpure assets. (2013). *Filtration and Separation, 50*(1), 4. doi:10.1016/s0015-1882(13)70005-3

Dossick, C. S., & Simonen, K. (2014). *Integrated AEC studio: iteration between analysis and design for interdisciplinary learning.* Washington: The building SMART alliance.

Dubois, A., & Gadde, L. (2002). The construction industry as a loosey coupled system:Implications for productivity and innovation. *Construction Management and Economics, 20*(7), 621-631. doi:10.1080/01446190210163543

Egan, J. (1998). *Rethinking Construction.* London: Department of the Environment, Transport and the Regions.

Frein, J. (2012). Handbook of construction management and organization. *Technology & Engineering*.

Haowen, Y. (2015). Innovative Technologies and their Application on Construction of a 100-Plus-Story Skyscraper. *International Journal of High-Rise Building, 4*(3), 161-169.

Harris , J. (2011). *Intergration of BIM and business stategy.* Evanston: BIM Libraries.

Harrison, A. J. (2013, March). Low carbon cements and concrete in modern construction. In UKIERI. *Concrete Congress–Innovations in Concrete Construction*, pp. 723-746.

HING, L. C. (2006). *Construction technology for high rise buildings in Hong Kong* . Queensland: Doctoral dissertation, University of Southern Queensland.

Hirlekar, R., Yamagar, M., Garse, H., Vij, M., & Kadam, V. (2009). Caebon nanotubes and its application: a review. *Asian Journal of Pharmaceutical and Clinical Research, 2*(4), 17-27.

Hu, L. (2016). Analysis on Technological Innovation of Civil Engineering Construction. *Engineering, 8*(5), 287-291.

ICTAD. (2013, may 15). *Insirute for construction traning and development.* Retrieved from contractor registaion: http://www.ictad.lk

ICTAD. (2016). Retrieved from http://www.landreclamation.lk/web/index.php?option=com_content&view=article&id=378%3Aictad-grading&catid=64%3Aspecial-notices&Itemid=104&lang=en

Ikeda, Y., & Harada, T. (2006). Application of the automated building construction system using the conventional construction method together . *23rd International Symposium on Automation and Robotics in Construction.* Tokyo, Japan.

IPS. (2002). National strategy for small and medium enterprise sector development in. *White Paper*. Retrieved from http://www.ips.lk/publications/series/gov_reports/sme_white_paper/sme_white_paper.html

Iwiss. (2008). *Electric rebar cutting and bending tools.* Iwiss Electric Co.Ltd. Retrieved from www.iwiss.com

Jaunzens, D. (2001). Influencing small businesses in the construction sector - through research.

Jonkers, H. M. (2011). *Bacteria-based self-healing concrete.* Heron, 56 (1/2).

Kang, T. K., Nam, C., Lee, U. K., Doh, N., & Park, G. T. (2011). Development of robotic-crane based automatic construction system for steel structures of high-rise buildings. *ISARC* (pp. 670-671). Seoul, Korea: ISARC.

Kavilkar, R., & Patil, S. (2014). Study of high rise residental building in Indian cities(A case study-Pune city). *International journal of Engineering and Technology, 6*(1), 86-90.

Khoshnevis, B. (2004). Automated construction by contour crafting -related robotics and Information Technology. *Automation in Construction, 13*(1), 5-19.

Kildienė, S., Zavadskas, E. K., & Tamošaitienė, J. (2014). Complex assessment model for advanced technology deployment. *Journal of civil engineering and management, 20*(2), 280-290. doi:doi:10.3846/13923730.2014.904813

Krishnan, L., Karthikeyan, S., Nathiya, S., & Suganya, K. (2014). Geopolymer concrete an eco-friendly construction material. Magnesium. *International Journal of Research in Engineering and Technology, 1*(1), 164-167.

Kyjakova, L., Mandicak, T., & Mesaros, P. (2014). Modern Methods of Constructions and Their Components. *Journal of Engineering and Architecture, 2*(1), 27-35.

Ling, F. (2003). Managing the implementation of construction innovations. *Construction Management And Economics, 21*(6), 635-649. doi:10.1080/0144619032000123725

Lloret, E., Shahab, A., Linus, M., Flatt, R., Gramazio, F., Kohle, M., & Langenberg, S. (2015). Complex concrete structures merging existing casting techniques with digital fabrication. *Computer-Aided Design, 60*, 40-49. doi:http://dx.doi.org/10.1016/j.cad.2014.02.011

Mbonyane, B., & Ladzani, W. (2010). Factors that hinder the growth of small businesses in South African townships. *Eur, 23*(6), 550-560.

McCuen, & Tamera. (2014). *The Challenges of Advancing BIM in the Curriculum while Addressing Current Accreditation Standards for Construction.* Washinton: The buildingSMART alliance.

Mehta, P. K. (1999). Advancements in concrete technology. *Concrete International -Detroit, 21*(1), 69-76.

Miyakawa, H., Ochiai, J., Oohata, K., & Shiokawa, T. (2000). *Application of Automated Building Construction System For High Rise Office Building.* isarc 2000-085_WB2.

Naguyen, T., & Chileshe, N. (2015). Revisiting the critical factors causing failure of construction projects in Vietnam . *Built Environment Project And Asset Mnagement, 5*(4), 398-416. doi:10.1108/bepam-10-2013-0042

Naji, B., Cottier, J. S., & lyons, R. (2005, May 17). *United States Patent No. US 6,893,751 B2.*

Navon, R., Rubinovitz, Y., & &Coffler, M. (1998). Rebar Computer Aided Design And Manufacturing. *Computer-Aided Civil and Infrastructure Engineering, 10*(6), 155-162.

Outokumpu. (2013). *Stainless Steel Reinforcing Bar Couplers.* Sheffield, United Kingdom: Outokumpu Stainless Ltd. Retrieved from www.outokumpu.com

Pan, Y., & Hou, L. (2016). Lifting and parallel lifting optimization by using sensitivity and fuzzy set for an earthmoving mechanism. (pp. 1-12). proceeding of the Institution of Mechanical Engineering. doi:DOI: 10.1177/0954407016660454

Prasanth, S. (n.d.). *Aluminium Form Work System.* Chenna: Grand Edifice Developers.

Puddicombe, M. (1997). Designers and Contractors: Impediments to Integration. *Journal Of Construction Engineering And Management, 123*(3), 245-252. doi:10.1061/0733-9364(1997)123:3(245)

Putzmeister. (2010). *Putzmeister Concrete Technology.* Germany: Putzmeister Concrete Pumps GmbH .

Richard, K. (1962). *Fiberglass Form Work.* , The Aberdeen Group.

Rosenberg, N. (2004). *Innovation And Economic Growth.* Stanford University, Economics. California: Stanford University.

Sakamota, S., & Mitsuoka, H. (1994). Totally Mechanized Construction System for High-Rise Buildings (T-UP System). In S. Sakamota, & A. D. Chamberlain (Ed.), *Automatic and Robotics in Construction XI* (p. 730). Boston: Newnes,2012.

Sandelin, C., & Budajev, E. (2013). *The Stabilization of High-rise Buildings: An Evaluation of the Tubed Mega Frame Concept.* Uppsala: Department of Engineering Science, Applied Mechanics, Civil Engineering, Uppsala University.

Schexnayder, C. J., & David, S. A. (2002). Past and Future of Construction Equipment-Part IV. *Journal of construction engineering and management, 128*(4), 279-286.

SGB-Group. (2005). *Cup Lock Scafold User Guide.* Leatherhead, Surrey: SGB Services Limited. Retrieved from www.sgb.co.uk

Shin, Y., Kim, T., Cho, H., & Kang, K. I. (2012). A formwork method selection model based on boosted decision trees in tall. *Automation in Construction, 23*(1), 47-54.

Slaughter, E. (1998). Models of Construction Innovation. *Journal Of Construction Engineering And Management, 124*(3), 226-231. doi:10.1061/(asce)0733-9364(1998)124:3(226)

Tatum, C. B., Vorster, M., & Klingler, M. (2006). Innovations in earthmoving equipment: new forms and their evolution. *Journal of construction engineering and management, 132(9), 987-997., 132*(9), 987-997.

Thalgodapitiya, & Dakshitha. (2008). Integrated approach needed to sustain construction industry. *sundaytimes*.

Thapa, C., Dhakal, D. R., & Dhakal, A. (2013). Construction Techniques and Demand Of High Rise Building In India. *International Journal of Emerging Trends in Engineering and Development, 2*(3), 46-51.

The Complete Guide to Portfolio Construction and Management Snopek. (2013). *Asset Classes*, 253 -258.

The Sunday Times. (2016, November 13). *Cold response to burning problem.* colombo: The Sunday Observer.

Thillairaja, S., Varun Yadav, K., VelMuruga, G., Venkatesan, S. P., Prabhakar, K., & Kumar, R. (2015). Reinforced bar bending machine. *Australian Journal of Basic and Applied Sciences, 9*(10), 290-294. Retrieved from www.ajbasweb.com

Vähä, P., Heikkilä, T., Kilpeläinen, P., Järviluoma, M., & Heikkilä, R. (2013). *Survey on automation of the building construction and building products industry.* Oulu: JULKAISIJA – UTGIVARE.

Väha, P., Heikkilä, T., & Kilpeläin, P. (2013). Extending automation of building construction — Survey on potential. *Automation in Construction, 36*(1), 168-178.

Vennstrom, A., & Eriksson, P. (2010). Client perceived barriers o change of construction process. *Construction innovtion: information, process, management, 10*(2), 126-137. doi:10.1108/14714171011037156

Vivian, W., Ivan, W. F., & Michael, C. (2015). Best practice of prefabrication implementation in the Hong Kong public and private sectors. *Journal of Cleaner Production, 109*(1), 216-231.

Walker, & Derek, H. (2000). Client or customer or stakeholder focus .ISO 14000 EMS as a construction industry case study. *The TQM Magazine, 12*(1), 18 - 26.

Warszawski, A., & Navon, R. (1998). Implementation of Robotics in Building: Current Status and Future Prospects. *Journal Of Construction Engineering And Management, 124*(1), 31-41. doi:10.1061/(asce)0733-9364(1998)124:1(31)

Wells, J. (1985). *The construction industry in the context of development* (Vol. 8). London: Pegamon Press Ltd.

Winch, G. (2003). How innovative is construction? Comparing aggregated data on construction innovation and other sectors – a case of apples and pears. *Construction Management And Economics, 21*(6), 651-654. doi:10.1080/0144619032000113708

Yehia, S., Douba, A., Abdullahi, O., & Farrag, S. (2016). Mechanical and durability evaluation of fiber-reinforced self-compacting. *Construction and Building Materials, 121*(1), 120-133.

Yu, K., Guan, Z. J., Cheung, T., T. T., & Lo, T. (2000). Applied Radiation and Isotopes. *Light weight concrete: 226Ra, 232Th, 40K contents and dose reduction assessment, 53*(6), 975-980.

Weinzimmer, L.G., Nystrom, P.C. and Freeman, S.J., 1998. Measuring organizational growth: Issues, consequences and guidelines. *Journal of management*, 24(2), 235-262.

Wiklund, J., 1998. *Small firm growth and performance: Entrepreneurship and beyond.* PhD Thesis: Jönköping International Business School.

Zahra, S., 1993. Environment, corporate entrepreneurship, and financial performance: A taxonomic approach. *Job of Business Venturing, 8*, 319–340.

DESIGN PROCESS STANDARDISATION FOR BUILDING PROJECTS IN INDIA

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ABSTRACT

The effectiveness of the design process significantly influences the performance of a building construction project. In a complex design environment, the advent of compressed fast-track schedules can cause disruptions in construction. It is, therefore, imperative to allocate appropriate efforts during design to minimize these disruptions. Thus, a framework which guides organizations to develop a well-structured design process will ensure better project delivery.

A preliminary study revealed that design processes in Indian construction industry were generally unstructured. A more detailed study of the design processes of four Indian developer organizations mapped the current design processes as swim lane diagrams. Analysis of these processes showed that design at each organization was driven by certain priorities and the design stage durations varied significantly, especially in the concept design stage where these priorities have maximum influence. Based on the analysis, it is apparent that standardization within an organization/project type is required and more feasible, than a single industry-wide standardization of the process.

This paper also presents a preliminary SIPOC (Supplier, Input, Process, Output, Customer) methodology to internally standardize design process which is derived from the maturity levels recommended in the Capability Maturity Model framework. This methodology has been used to develop generic process charts from the design processes mapped for the organizations sampled. It is anticipated that the availability of these standards will enable better planning and monitoring of building design.

Keywords: *Design Duration; Variability; SIPOC Methodology; Standard Process.*

1. INTRODUCTION

The design process involves identification of customer requirements and their translation into design specifications. As the design is complex, efficient management of design process is necessary to ensure that issues stemming from design have minimal impact on the construction process. Complexity in design arises from the fact it is iterative, interdisciplinary, and done by specialists from different teams.

Modern construction projects have challenging schedule requirements. To compress the schedule, strategies such as fast-tracking and concurrent engineering are adopted. These strategies put additional pressure on the design phase and this coupled with other issues such as inadequate technical knowledge (Gadhavi, 2010), poor information flow, need to generate multiple design alternatives (Gane *et. al*., 2010) deficient planning, omissions, erroneous information and design changes (Venkatachalam and Varghese, 2010) render ineffective design. Inadequate design result in delays, rework and variations impacting project time and costs (Tilley and Barton, 1997).

Based on industry inputs obtained from an exploratory review meeting with industry participants and subsequent discussions it was identified that developing a standard for the building design process would enable better management of design. Based on the exploratory study and detailed inputs from the participating organizations it was found that as project types and requirements varied widely, it was not practical to have a standardized building industry-wide design process. However, the process for a specific project type within an

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organization could be standardized. Further, the methodology to develop the standard could also be framed, thus making it applicable to develop a standard for any project type within any organization.

Application of this methodology to develop standards is also critical for the Indian building industry in light of recent developments such as Real Estate Regulatory Act (RERA). As shown in Figure1, the Act requires design for sanction to be complete (with no changes permitted) before the start of sales. In comparison, the practice before RERA did not require design to be complete at this stage and hence as it can be seen from the Figure, that the cash flow risk in a project is reduced when design durations are predictable. To enable better management and estimation of design durations, design process standards are a necessity.

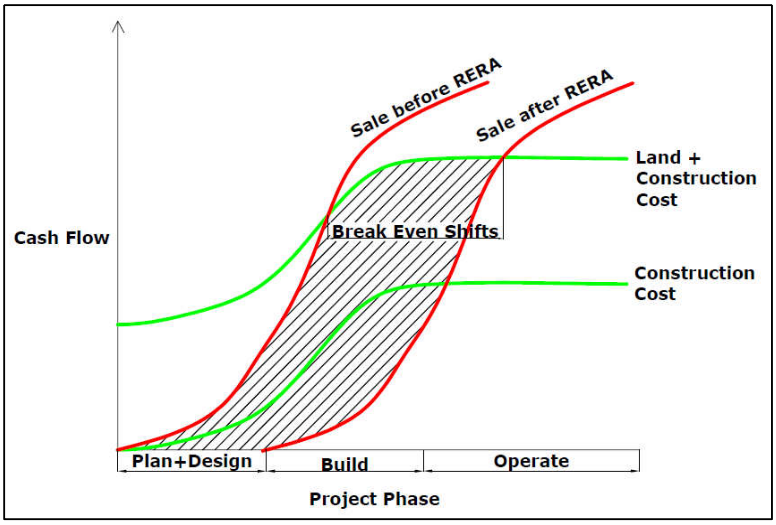

Figure 1: Impact of RERA on Project Cash Flow

Based on the need identified above, preliminary data collection and analysis was done towards developing a standard. This revealed that standardization for building process could be done at 3 levels- process mapping, duration assessment and methodology formulation. The overall objectives of this study were defined based on these levels and are (i) develop a generic process template based on type of project, (ii) determine average duration of different design stages based on project data (iii) develop a methodology by which an organization could map a standard process, gather data for specifying stage durations and continuously improve it design process performance. The third level was identified based on the observation that both the process template and the durations can vary based on the specific needs of an organization and project type. Of these objectives, the first one is discussed in detail in this paper, the approach to the other two objectives are also presented.

The scope of the study is limited to the (i) Design process for building projects. (ii) The generic templates are developed only for residential and commercial projects. (iii) Data from 13 projects are used to derive the stage duration standards (iv) The proposed methodology is validated through expert opinion.

2. LITERATURE REVIEW

Several studies have identified the influence of design management on the overall success of a project. These studies have revealed issues such as poor planning and management and ineffective communication leading to inefficiencies in the design process. (Koskela *et al*., 2002; Williams *et al*., 2013). Design processes are subjected to variation in time, cost, scope and design construction interface (Anderson *et al.*, 2005). Most of the research has been focusing on improving design from a designer's perspective with minimal incorporation of organizational and project specific issues (Tzortzopoulos *et al.*, 2007). Mapping of the design process has been attempted in the past with the aim to apply rational models of decision-making and systems engineering methodologies to the process of design (Hughes, W., 2003).

The construction industry is found to be deficient in developing a systematic scheme to improve design management practices (Tzortzopoulos *et al.*, 2007). Lack of conceptual base is the major reason for the poor level of design management. Further, application of tools and techniques for design improvement call for the development of an appropriate framework of the design process (Formoso *et. al.*, 1998). Through the development of standards, failures attributed to errors and omissions in design can be reduced (Williams *et al.*, 2013).

The RIBA plan of work in the UK (RIBA Plan of Work, 2013), for example, provides a framework for building design and construction process and a guideline to define the role of an architect (Alsaadani and De Souza, 2016) through the entire lifecycle of the project (Hughes, 2003). However, such plan of work have been criticized due to the lack of 'systems' view of management and therefore offering little more than a checklist and due to lack of control and boundary features (Hughes, 1991). A company-specific standard can aid in efficient design management and effective use of available resource es (Chhabra and Rathore, 2011).

Design management in India can be characterized by the lack of a standardized plan of work and hence the inability to provide the necessary framework for the activities in the various project phases. Several standards such as RIBA Plan of Work, CIC Scope of Services and CIA-India standards are available and widely used in international practice. There is an absence of similar standards in the Indian context and in addition to developing broad process standards, there is a need customize the standards for specific project types or organizational objectives. To address this need, a study to address specific design process issues in the Indian context was required.

3. METHODOLOGY

The area of design management was identified and reported as an action area in the first meeting with industry representatives (Ci3 India, 2016a). Based on this a team was formed to identify and prioritize the areas to be studied under design management. Standardization was a key area identified by the action group. The study methodology followed by this action group is illustrated in Figure 2 below and each of the steps is described in further detail:

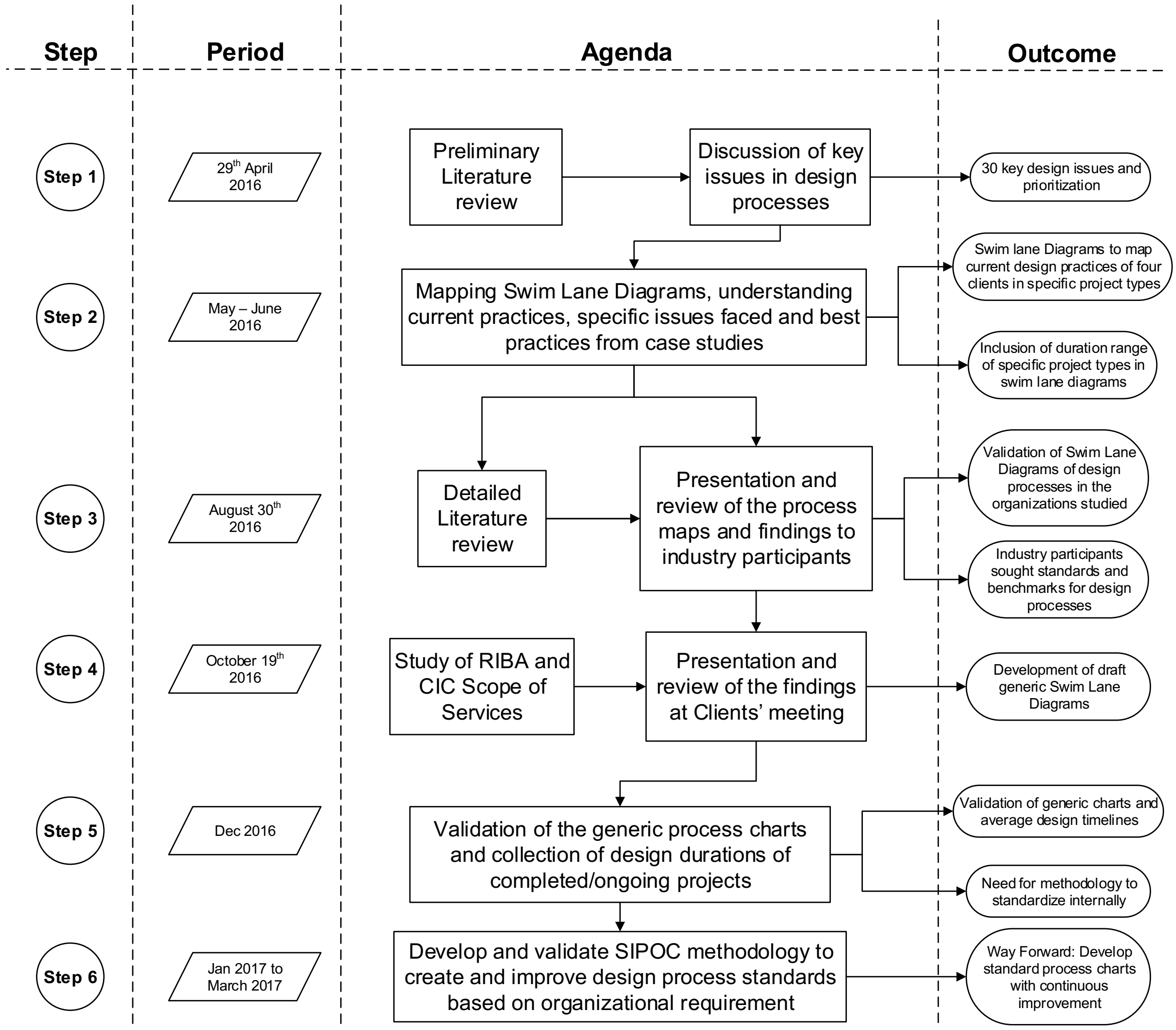

Figure 2: Study Methodology

Step 1: A focus group of 5 industry representatives and 3 academics discussed the key issues in design processes, faced by the industry in the Indian context specifically. Several points were discussed and 30 key issues were identified (Ci3 India, 2016b).

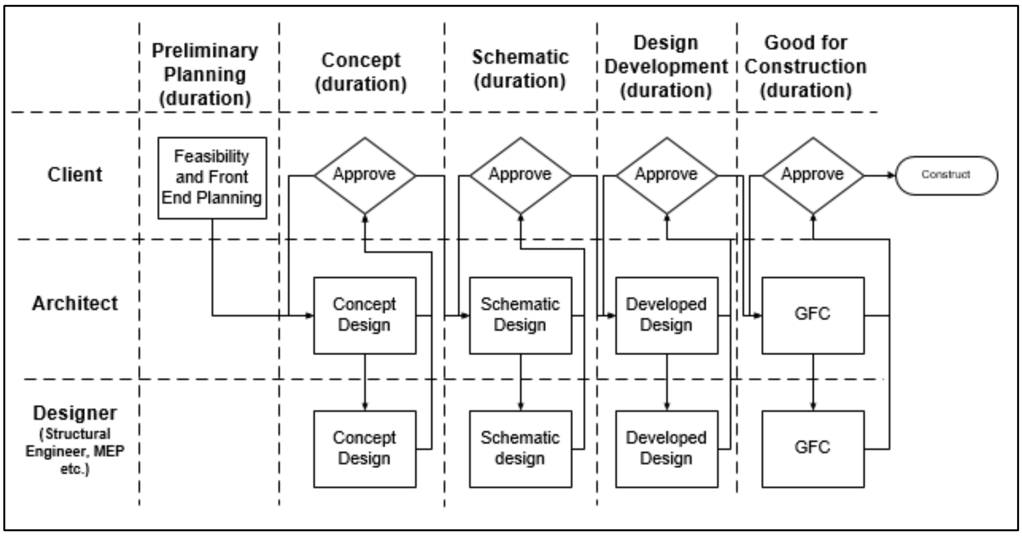

Figure 3: Format of the Generic Process Chart

Step 2: In order to establish current design procedure, identify specific design issues and best practices, four client organizations were visited and the process charts of specific project cases were mapped using swim lane diagrams. The stage wise design duration ranges of specific project types of these organizations were also incorporated in the swim lane diagrams. The format of the swim lane diagrams mapped is presented in Figure 3.

Step 3: Findings from literature and the developed swim lane diagrams were presented at a review meeting, to the 4 organizations which participated in the data collection process. During this meeting, the diagrams were reviewed, validated and the industry representatives sought standards and benchmarks for design processes. (Ci3 India, 2016c)

Step 4: The results from the review meeting and findings from earlier stages were presented and reviewed at a Clients' and Consultants' meeting. With reference to the process charts of the organizations, draft generic process charts were formulated. (Ci3 India, 2016d).

Step 5: Client organizations were revisited at their corporate offices to validate the generic swim lane diagrams and collect the design timeline data for completed and ongoing projects. Suggestions on the generic charts from the industry participants were incorporated and design duration of 5 residential projects and 8 commercial projects were collected. As seen in Figure 2, the outcome of this step was average timelines for design durations and a procedure to develop standard processes on swim lane diagrams.

Step 6: This step proposes a methodology to develop and continuously improve the design process standards, based on organizational requirements. This methodology is discussed in the "Way Forward" section of this paper.

4. RESULTS AND INFERENCES

The key results from the study are presented in this section and the inference drawn from these results are discussed. With reference to Figure 2, the results presented in this section are outcomes from Steps 2 and 3.

1. *Priority-driven process charts in organizations*

At Step 2 and 3 of the methodology, shown in Figure 2, it was observed from the processes mapped in the form of swim lane diagrams, that invariably every organization (or types of projects done by organizations) had a specific design objective and strategies to achieve those objectives.

Table 1: Key Attributes of Organizations Visited

Organization	Type of Organization	Type of Projects	Design Objective	Strategy for Achieving Objective
1	Real Estate developer	Residential, Commercial, Hospitality	Timely design and project delivery	Concurrent design stages for fast track
2	IT firm	IT offices	Landmark structure with operational efficiency	Collaborative approach to design with emphasis on operational efficiency from initial phases
3	Real Estate and Infrastructure	Mixed use	Maximize return on investment	Evaluate more concept options based on changing market trends
4	Real Estate developer and redevelopment	Mixed use and redevelopment	Meet planned budget	Check budget/revenue compliance after each design stage

The key attributes of each of the organizations are presented in Table 1. Organisation 1 attempts expedited project delivery through concurrent design. Organization 2, which is a renowned IT firm looks to design and develop iconic projects for their own use, with an impetus to life cycle cost. Organization 3 has a design approach which is flexible to incorporate demands of changing market trends, even midway through the design. Organization 4 targets to achieve the budget proposed at commencement by ensuring compliance at every stage of design. It is inferred from the above Table that each organization has its own priorities. Therefore, developing standards with design activities to suit their type of need is more relevant than following an industry-wide standard.

2. *Variability in design durations across organizations*

Duration ranges of the different design stages for specific project types in each of these organizations were also assessed as a part of Step 2 of the methodology. This assessment was based on the need to explore the effect of the specific design activities catering to organization/project priorities, on the duration of design stages.

The duration of the design process is largely dependent on the priority of the organization/project needs. The architect may use art as a medium to meet various organizational/project priorities and may develop different numbers of concept options, thus causing variability.

Figure 4 graphically represents the comparison of organizational averages of the stage duration (derived as the mean value of the range). As observed in the chart, among the 5 stages in design, the maximum variation in duration between the 4 organizations is found to be in the concept stage. The implementation of the specific design objectives presented in Table 1, seems to have a significant impact on the conceptual stage of design. This reinforces the need for organizations to standardize the durations of the design stages based on organization/project objectives.

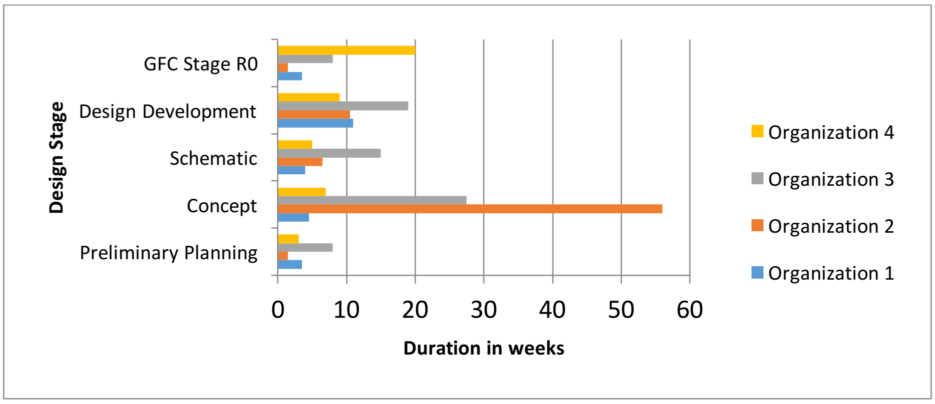

Figure 4: Graphical Comparison of the Duration of Design Stages

3. *Range of stage wise design durations within organizations*

The range of design time taken by different organizations for their specific project types, collected at Step 2 and confirmed through discussions at Step 4 of the Methodology, is presented in Table 2. It is inferred from this that that significant variability exists within an organization for similar project types. Availability of design standards with defined activities and expected durations can enable organizations to reduce this variability.

Table 2: Range of Stage Durations in Organizations (Duration in weeks)

Organization	**1**	**2**	**3**	**4**
Preliminary Planning	2 to 5	1 to 2	8	2 to 4
Concept	3 to 6	52 to 60	21 to 34	6 to 8
Schematic	3 to 5	4 to 9	13 to 17	4 to 6
Design Development	6 to 16	8 to 13	17 to 21	8 to 10
GFC drawings	3 to 4	1 to 2	8	16 to 24

At Step 4 and Step 5 of the methodology, the above findings were presented to the participating clients. The forum participants were of the general opinion that the mapping of the design process and timelines would be of value in enabling better planning and monitoring of the design phase. As specific organizations requirements vary, generic process charts templates for residential and commercial projects were developed in the format shown in Figure 3.

5. WAY FORWARD

Participating organizations are expected to use the above references as a base to formulate their own process charts, aligned with the priorities. Standards will have to be made based on classifications of the targeted customer pools for different project types.

As these standards will require being assessed and improved periodically, further work in this area focuses on approaches to achieve this continuous improvement cycle. The CMMI (Capability Maturity Model Integration) suggests process benchmarking at 5 maturity levels – Chaotic, Repeatable, Standardized, Quantitatively measured and Optimizing (CMMI, 2010). Based on this, a preliminary SIPOC (Supplier, Input, Process, Output, Customer) methodology for developing a standard process chart is illustrated in Figure 5 below.

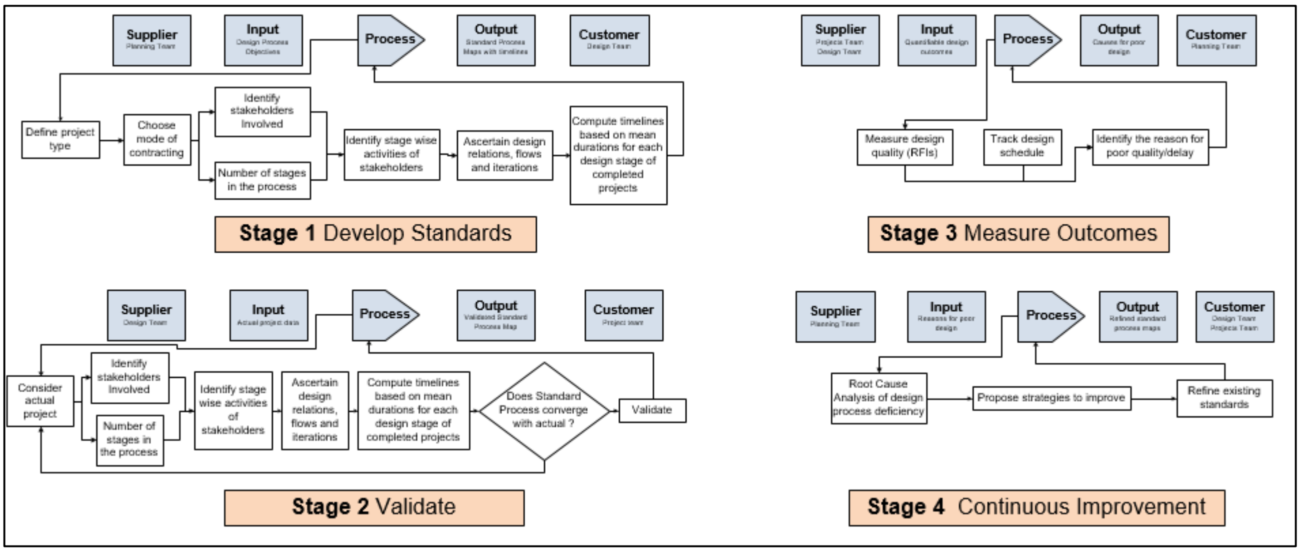

Figure 5: Stage-wise SIPOC Methodology to Develop Standard Process Chart

Each stage in the methodology represents a transition from one CMM level to the next. Therefore, organizations need to first benchmark the level of design process maturity within the organization and then choose the relevant stage in this methodology to move up the maturity ladder. This proposed methodology has been validated through interviews and other industry interactions.

6. SUMMARY

An exploratory study was carried out to identify design issues faced by Indian construction industry. Analysis of detailed design data collected from four Indian construction clients, by mapping the current practices on swim lane diagrams, revealed certain fundamental differences across the organizations. Proposals to address these differences and to improve design processes have been recommended in this paper and have been validated. The following are the key conclusions from this study:

1. Design development in different organizations/project types is driven by specific organizational and project priorities. There are variations in the process stage relationships based on the organization's strategy to achieve its objectives.
2. These priorities also had an influence on the design durations, especially the duration of concept stage, where the influence of priorities was high.
3. The generic process charts developed as a part of this study can be used by an organization to develop a more specific process based on their requirements.

Based on the feedback from several respondents, the development of these standards is expected to enable better management of the design phase. The validation of the SIPOC methodology by implementing in actual projects will form a part of the future work.

7. REFERENCES

Alsaadani, S. and De Souza, C. B, 2016, Of collaboration or condemnation? Exploring the promise and pitfalls of architect-consultant collaborations for building performance simulation, *Energy and Social Science,* 19, 21-36.

Anderson, J., Nycyk, M., Jolly, L. and Radcliffe, D. 2005, Design Management in a Construction Company, In *Proceedings of the 2005 ASEE/AaeE 4th Global Colloquium on Engineering Education*, Australasian Association for Engineering Education, 1-10.

Chhabra, A. and Rathore, N. 2011, Review of design management processes and efficacy of BIM with a view to evolving a new conceptual framework of an integrated approach for the AEC industry. In: Chakrabarthi, A. *Research into Design- Supporting Sustainable Product Development,* Chennai, 368-376.

Ci3 India, 2016a, Summary of Regional Roundtable, 14th October 2015 Available from: http://www.ci3.in/outputs/reports/regional_report.pdf [Accessed 10 August 2016]

Ci3 India, 2016b, Action Team 3 Minutes of Meeting, Workshop on 29th April 2016

Ci3 India, 2016c, Action Team 3 Minutes of Review Meeting, Ci3 India Action Team 3A, 30th August 2016

Ci3 India, 2016d, Summary of Ci3 India Clients' and Consultants' Roundtable, 19th October 2016 Available from: http://www.ci3.in/outputs/reports/consolidation_report.pdf [Accessed 20 December 2016].

CMMI, 2010, *CMMI for Development, Version 1.3 Technical Report - Improving Processes for developing better products and services*, November, 2010. Available from: https://resources.sei.cmu.edu/asset_files/TechnicalReport/2010_005_001_15287.pdf [Accessed 21 August 2016].

Formoso, C.T., Tzotzopoulos, P., Jobim, M.S.S. and Liedtke, R., 1998, Developing a Protocol for Managing the Design Process in the Building Industry, In:, *6th Annual Conference of the International Group for Lean Construction*. Guarujá, Brazil, 13-15 Aug 1998.

Gadhavi, P, 2010, *Identification of Critical Competencies for Design Management,* M.Tech Dissertation, Department of Civil Engineering, Indian Institute of Technology Madras, Chennai

Gane, V. and Haymaker, J., 2010, Benchmarking current conceptual high-rise design processes, *Journal of Architectural Engineering*, 16(3), 1-5.

Hughes, W. P., 2003, A comparison of two editions of the RIBA Plan of Work, *Engineering, Construction and Architectural Management*, 10(5), 302 - 311

Hughes, W., 1991, Modelling the construction process using plans of work, In *4th Yugoslav Symposium on Organization and Management in Construction*, Dubrovnik, Yugaslavia 1991, 81-86.

Koskela, L. J., Huovila, P. and Lenonen, J. 2001, Design management in building construction: From theory to practice, *Journal of Construction Research,* 3(1), 1–16

RIBA Plan of Work, 2013. [online]. Available from https://www.ribaplanofwork.com/ [Accessed 16 May 2016].

Tilley, P. A. and Barton, R., 1997, Design and documentation deficiency- causes and effects. In *Proceedings of the First International Conference on Construction Process Reengineering*, Gold Coast 14-15 July 1997. Australia, 703-712.

Tzortzopoulos, Patricia, Cooper, and Rachel, 2007, Design management from a contractor's perspective: the need for clarity. *Architectural Engineering and Design Management*, 3(1), 17-28.

Venkatachalam, S. and Varghese K., 2010, Analysis of Workflow on Design Projects in India, *Design Management and Technology*, 5(3), 85-103.

Williams, C. Jr. and Johnson, P., 2013, Standards of professional practice for design management. *Journal of Professional Issues in Engineering Education and Practice*, 140(2), 1- 4.

ECOLOGICAL FOOTPRINT TO EVALUATE ENVIRONMENTAL SUSTAINABILITY OF APPAREL SECTOR BUILT ENVIRONMENTS: THE SRI LANKAN PERSPECTIVE

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ABSTRACT

Accelerated human pressure on earth has necessitated adopting environmental footprints to evaluate environmental sustainability. Ecological Footprint (EF), Carbon Footprint (CF) and Water Footprint (WF) are common environmental footprints used to evaluate environmental sustainability globally. Although there is a growing interest for calculating CF and WF, there is a lack of application of EF for environmental sustainability evaluation in Sri Lankan apparel sector. Therefore, this research investigates the applicability of EF to evaluate environmental sustainability in apparel sector built environments in Sri Lanka. Research scope was limited to evaluate environmental impacts of energy consumption, water utilisation and waste generation in apparel sector built environments.

A qualitative research approach was followed to pursue the research aim. A comprehensive literature review was conducted to review the concept of EF and the relationship of EF with CF and WF. Subsequently, three apparel sector factories were investigated in detail to identify the nature of EF application in Sri Lanka and collected data was subjected to content analysis. Findings revealed that, even though EF is not currently fully calculated, it is partially evaluated through quantification of CF and Grey WF. It was also revealed that EF can be practiced to evaluate environmental sustainability in apparel sector built environments in Sri Lanka. Difficulty to understand the underlying assumptions of EF of water utilisation and EF of waste generation was identified as the main barrier. Providing training and awareness on the application of EF, raising awareness on calculating EF of water utilisation and EF of waste generation are some of the strategies to overcome barriers.

Keywords: *Apparel Sector Built Environments; Carbon Footprint; Ecological Footprint; Environmental Sustainability; Water Footprint.*

1. INTRODUCTION

With the escalating world population growth, resource consumption has surpassed the regeneration capacity of earth (Toth and Szigeti, 2016). Environmental sustainability is conceptualised based on the notion of eco system services of resource consumption and waste absorption capacity (Moldan *et al*., 2012). Environmental footprints are indicators that used to evaluate environmental sustainability (Čuček *et al*., 2012). Čuček *et al*. (2015) identified EF, CF and WF as the most commonly used environmental footprints among other footprints such as Energy Footprint, Nitrogen Footprint, Phosphorous Footprint, Land Footprint, Bio diversity Footprint.

Wood and Lenzen (2003) argued that due to the diverse scope of EF, it can be considered as the main indicator, which addresses the broad spectrum of sustainability. According to Kitzes *et al*. (2007), the Global Footprint Network (GFN) takes the leadership in improving national footprint accounting and footprint standardisation. GFN (2017) defined EF as "a measure of how much area of biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices". EF is a successful indicator for measuring environmental impacts, since it can be used with WF and CF (Galli *et al*., 2007).

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Although the EF was initially developed to assess the environmental impacts of individuals and nations in the global context, it is being widely used as an environmental sustainability indicator at industrial, organisational and products levels (Weidmann and Barrett, 2010). Herva *et al*. (2008) suggested the application of EF to textile sector in order to evaluate the environmental impacts of manufacturing factories and production processes. Munasinghe *et al*. (2016) emphasised about growing interest in Sri Lankan apparel sector for applying CF to evaluate environmental sustainability. Herath (2015) stated that applying WF concept for Sri Lankan apparel sector helps in reducing water consumption, which in turn minimises environmental impacts. Although the application of CF and WF to evaluate environmental sustainability is trending, lack of an investigation in to the applicability of EF in apparel sector built environments in Sri Lanka is evident. Hence the aim of this research is to investigate the applicability of EF in apparel sector built environments in Sri Lanka.

This paper starts with a literature review on the concept of EF and the relationship of EF with CF and WF. The research methodology is presented in section 3 followed by data analysis and research findings. The paper finally presents conclusions of the study and provides the recommendations.

2. LITERATURE REVIEW

2.1. *THE CONCEPT OF ECOLOGICAL FOOTPRINT*

EF acts as an overall indicator, which measures environmental impacts (Van den Bergh and Grazi, 2013) and can be used as an indicator to quantify resource consumption and waste generation (Figge *et al*., 2016). Rees and Wackernagel (1996) defined EF as the total productive land and water area needed to generate resources consumed and absorb waste generated of a specific population or economy. It is generally measured in terms of global hectares (Galli *et al*., 2007). There are six categories of biologically productive lands namely, crop land, forest land, built up land, fishing ground, pasture land and carbon uptake land (Borucke *et al*., 2013). Table 1 explains about the biologically productive land categories, employed for EF accounting.

Table 1: Biologically Productive Land Categories

Land Types	Description
Crop Land	Provides plant based food and fibre products
Built-up Land	Provides built-up surface for shelter and infrastructure
Fishing Ground	Provides marine and inland area for fish products
Pasture Land	Provides animal products and grass
Forest Land	Provides timber and other forest based products
Carbon uptake Land	Sequestration of carbon dioxide by forests

(Adapted from: Borucke *et al*., 2013)

In EF accounting, with respect to the aforementioned biologically productive land categories, equivalence factors and yield factors are the two important coefficients to be informed of (Borucke *et al*., 2013). The equivalence factor converts a land type in to a universal unit of a biologically productive area and the yield factor measures the productivity of a land type in different countries (GFN, 2017).

2.2. *RELATIONSHIP BETWEEN THE ECOLOGICAL FOOTPRINT WITH OTHER FOOTPRINTS*

Galli *et al*. (2012) integrated EF, CF and WF in to a common set called footprint family, since they complement, overlap and interact each other. CF accounts for greenhouse gas (GHG) emissions and WF accounts for fresh water consumption (Galli *et al*., 2013). EF and CF are overlapping since EF quantifies the required biologically productive areas to absorb the GHG, carbon dioxide (Galli *et al*., 2012). The authors further explained that EF and WF are partially overlapping since the biological capacity of earth is influenced by water. Hoekstra (2009) highlighted the sub components of the WF as Blue WF, Green WF and Grey WF. Table 2 summarises the relationship of EF with CF and WF.

Table 2: Relationship between Ecological Footprint with Other Footprints

Indicators	Relationship
EF vs CF	Indicators are overlapping Carbon uptake land accommodates CF by accounting for sequestration of carbon dioxide emissions CF originated as a sub set of EF CF is a sub category under EF
EF vs WF	Indicators are partially overlapping A biologically productive land category is not assigned to quantify fresh water consumption WF originated as an analogue of EF WF is not a sub category under EF

(Sources: Borucke *et al*., 2013; GFN, 2017)

As tabulated above, EF has a strong relationship with CF, since it is a sub set of EF and moreover the relationship between the EF and WF is manifested due to partial overlapping between the two indicators.

2.3. *APPLICABILITY OF ECOLOGICAL FOOTPRINT IN APPAREL SECTOR*

Despite its major contribution to economic development, textile industry consumes a large amount of energy, water and it uses chemicals, which generate waste products (Jaganathan *et al*., 2014). Niinimäki and Hassi (2011) stated that textile industry provides basic materials and apparel industry converts these materials to meet the demand of consumers. Therefore, both industries are responsible for creating environmental impacts through energy consumption, water utilisation and waste generation. Since energy consumption, water utilisation and waste generation in apparel sector create adverse environmental impacts, determining the EF of these three impact categories is of paramount importance. Therefore, Butnariu and Avasilcai (2014) proposed EF as a tool to assess the environmental performance of apparel manufacturing factories and their manufacturing processes in order to optimise resource utilisation and minimise waste generation.

2.4. *ECOLOGICAL FOOTPRINT OF ENERGY CONSUMPTION, WATER UTILISATION AND WASTE GENERATION*

Butnari and Avasilcai (2014) explained that land category allocated to absorb carbon dioxide emissions from combustion of fossil fuels to generate energy is known as fossil land. According to the authors, since the energy consumed in apparel manufacturing processes comprises of electricity and fuels, EF of fuel usage and EF of electricity consumption is assigned to fossil land. Similarly, Herva *et al*. (2008) assigned fossil energy land to determine EF of fuel usage and EF of electricity consumption. Therefore, carbon uptake land is also known by the terms, fossil land and fossil energy land. It can be deduced that EF of energy consumption is assigned to carbon uptake land.

EF of water consumption is assigned to forest lands assuming forest as a water producer (González-Vallejo *et al*., 2015). However, Kitzes *et al*. (2007) stated that the National Footprint Accounts does not recognise assigning a land category for fresh water consumption. Therefore Martínez-Rocamora *et al*. (2016) suggested to quantify the impacts of water consumption, in terms of energy utilised in treating waste water generated. Accordingly, EF of water utilisation is assigned to carbon uptake land.

Tian *et al*. (2012) stated that biologically productive land category of waste generation is determined based on waste type and waste disposal process. Hence waste disposal and emissions have to be accounted and the share of energy recovered by recycling must be deducted (Herva *et al*., 2008).

According to literature findings, EF of apparel sector built environments is mainly quantified by EF of energy consumption, EF of water utilisation and EF of waste generation.

3. RESEARCH METHODOLOGY

The research design provides the plan to discover answers to the research problem through various research strategies (Saunders *et al*., 2009). This research was initiated with a literature survey to review the concept of EF and to identify the relationship between EF with other environmental footprints. The literature review was followed by a background study, which revealed that, EF is a new concept to Sri Lankan context and only few apparel sector factories are evaluating environmental footprints. Based on the comprehensive literature review and the background study, following research problems were developed.

- How EF is currently evaluating in apparel sector built environments in Sri Lanka?
- What are the barriers to apply EF in apparel sector built environments Sri Lanka?
- How to overcome barriers to apply EF in apparel sector built environments in Sri Lanka?

Yin (2011) explained that qualitative approach contributes to explore emerging concepts and is most suitable for researches which have small sample of respondents. Since EF is relatively new to Sri Lanka and only few apparel sector factories are currently evaluating environmental footprints, case studies were undertaken under qualitative approach to facilitate an in depth investigation. Accordingly, three apparel manufacturing factories which evaluate environmental footprints were selected as cases.

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, 2002). Three respondents from each case, who involve in the current footprint evaluation process were interviewed. Moreover, observations and reviewing relevant documents were undertaken to capture data. Qualitative data analysing was conducted to analyse collected data using content analysis. Research findings were presented to an industry expert and an academic expert for validation and the final outcome of the research was refined accordingly. The profile of the case study factories and respondents is summarised in Table 3.

Table 3: The Profile of the Case Study Factories and Respondents

Case Name	Description of Case	Respondents	Description of Respondent
Factory A	• BOI approved apparel manufacturer and exporter, located outside Industrial Zone of Ekala • The factory manufactures loungewear and operates a fabric washing and colouring plant • The factory is a single storey building of 11400 m^3 and has 683 employees	A1	Group Facility Manager with 17 years of work experience, and responsible for evaluating footprints and formulating action plans
		A2	Senior Maintenance Executive with 10 years of work experience, and responsible for calculating footprints and monitoring data collection procedure
		A3	Senior Maintenance Technician with 11 years of work experience, and responsible for collecting and recording data for footprint calculations
Factory B	• BOI approved apparel manufacturer and exporter, located in EPZ of Katunayake • The factory manufactures sportswear • The factory is a single storey building of 9800 m^3 and has 550 employees	B1	Director of Compliance with 27 years of work experience, and responsible for analysing footprints for decision making
		B2	Engineering Executive with 08 years of work experience, and responsible for calculating and interpreting footprints
		B3	Maintenance Officer with 10 years of work experience, and responsible for collecting data for footprint calculations
Factory C	• BOI approved apparel manufacturer and exporter, located in Ratnapura • The factory manufactures lingerie • The factory is a single storey building of 9500 m^3 and has 472 employees	C1	Maintenance Manager with 21 years of work experience, and responsible for assessing footprints and formulating strategies
		C2	Factory Engineer with 15 years of work experience, and responsible for calculating and interpreting footprints
		C3	Maintenance Supervisor with 14 years of work experience, and responsible for collecting and recording data for footprint calculations

To capture data through unstructured interviews, one managerial level respondent, one executive level respondent and one non-executive level respondent were chosen as per the role they perform in the data collection for footprint calculations, calculation of footprints and evaluation of results for decision making through footprint calculations.

4. RESEARCH FINDINGS AND DISCUSSION

The following section presents the case study findings on

- Situational analysis on evaluating EF in apparel sector built environments in Sri Lanka
- Barriers in applying EF in apparel sector built environments in Sri Lanka
- Strategies to minimise barriers in applying EF in apparel sector built environments in Sri Lanka

4.1. SITUATIONAL ANALYSIS ON EVALUATING ECOLOGICAL FOOTPRINT IN APPAREL SECTOR BUILT ENVIRONMENTS IN SRI LANKA

All the respondents at factories A, B and C stated that other than the CF and WF, no other footprint calculation is done and thus these factories currently do not calculate EF. Respondents were requested to state currently calculated footprint indicators to evaluate the environmental impacts of energy consumption, water utilisation and waste generation.

CF is calculated to quantify the environmental impacts of energy consumption in respondent factories through fuel usage and electricity consumption. B1 commented, *"We already account for carbon emissions under CF. So, the EF of energy consumption is accounted using carbon emissions, but without converting to carbon uptake land"*. Accordingly, in order to calculate EF of energy consumption in respondent factories, data on CF of fuel usage and CF of electricity consumption should be computed. Furthermore, C3 emphasised, *"all necessary data is already available through CF calculation process to commence EF of energy consumption calculation"*. As per the respondents, partial practice of EF can be realised due to calculation of CF, which is a sub category of EF.

Respondents claimed that, current calculation of Grey WF, which is a sub category of WF, facilitates the quantification of waste water generated. Therefore, calculating Grey WF is an indication that waste water is treated at factory level and energy consumed in treating waste water can be quantified. B2 pointed out, *"EF methodology does not directly assign land categories to water consumption"*. According to A1, *"there is no land category assigned for water consumption related impacts, but there should be a way to compute those impacts under EF"*. Nevertheless, literature findings revealed that quantifying EF of water utilisation can be achieved by computing waste water treatment. Since all the respondent factories treat waste water using effluent treatment plants, which are operated from electricity, EF of energy consumption for treating waste water in a respondent factory should be deducted from total EF of electricity in that factory as explained under literature synthesis. Therefore, quantification of impacts of waste water generation through Grey WF calculations immensely facilitates potential to calculate EF of water utilisation.

Further it was revealed from the responses, environmental impacts due to waste generation are not quantified under currently practicing footprints. Since majority of waste products are processed by third parties, their impacts could not be quantified at factory level. B2 explained about assigning a land category to compute EF of waste generation in factory as, *"When it comes to waste types, impact of each and every waste should be considered to account under EF, for which the waste management strategy of each of them has to be known. But at our factory level, waste generation does not create adverse environmental impacts, since waste is handled by third parties"*. When waste products are processed by third parties, energy recovered from recycling and other processing methods cannot be quantified by the respondent factories to quantify EF of waste generation.

As expressed by majority of respondents, availability of necessary data on energy consumption, water utilisation and waste generation enables calculating EF. B3 emphasised, *"we already have energy, water and waste related data. If the calculation methodology is known properly, these data can be used to do EF calculation"*. Summary of the responses given by all the respondents is tabulated in Table 4.

Table 4: Footprints Evaluate in Case Studies Factories

Impact categories	Sub Categories	Footprint Indicator		
		Factory A	Factory B	Factory C
Energy Consumption	Direct emissions due to fuel usage in the factory	CF	CF	CF
	Indirect emissions due to electricity consumption in the factory	CF	CF	CF
Water Utilisation	Impacts due to waste water generation in the factory	Grey WF	Grey WF	Grey WF
Waste Generation	Impacts due to waste products generation in the factory	Not quantify	Not quantify	Not quantify

Moreover, through document reviewing and observations made at respondent factories, currently practicing strategies to minimise CF and WF in the respondent factories which contribute to reduce EF of energy consumption, EF of water utilisation and EF of waste generation were identified. The research findings revealed that, EF is not currently fully calculated in all three factories. All the respondents acknowledged that, they have the potential to calculate EF for evaluating environmental sustainability in their factory buildings. After computing the data captured from respondent factories and mapping them with literature findings, the related biologically productive land category to which the impact categories, energy consumption, water utilisation and waste generation are assigned should be determined as illustrated in Figure 1.

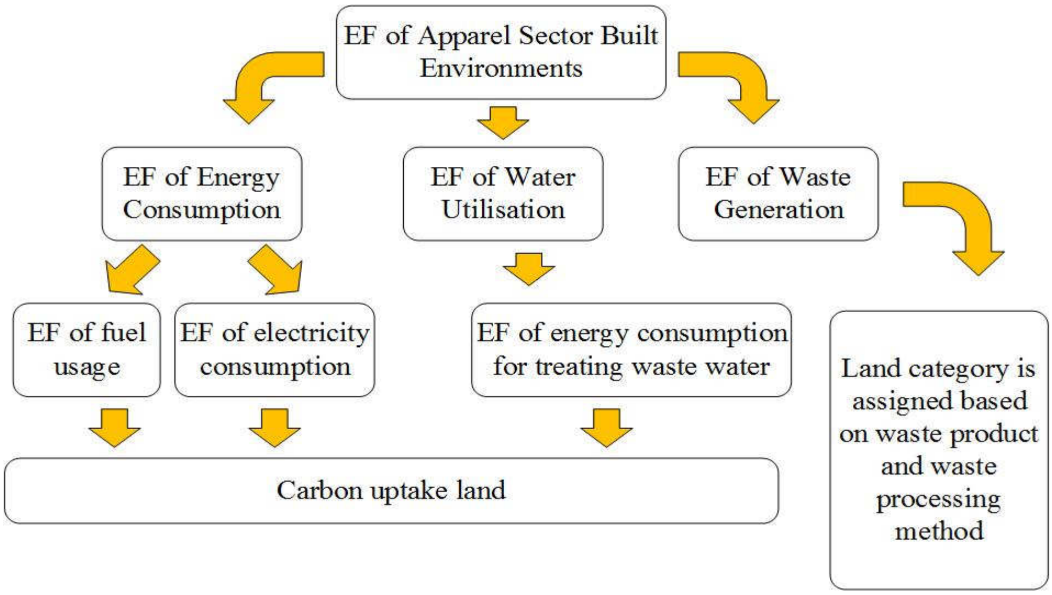

Figure 1: Assigning Land Categories to Impact Categories

As illustrated above, EF of energy consumption and EF of water utilisation are assigned to carbon uptake land and EF of waste generation is determined as per the waste product and waste processing method.

4.2. BARRIERS IN APPLYING ECOLOGICAL FOOTPRINT IN APPAREL SECTOR BUILT ENVIRONMENTS IN SRI LANKA

Barriers which constrain the successful applicability of EF were determined through the opinions of respondents. Accordingly, difficulty of understanding underlying assumptions of EF of water utilisation and EF of waste generation was identified as the major barrier to apply EF to evaluate environmental sustainability in apparel sector built environments in Sri Lanka. A1 emphasised his opinion as *"Although the calculation of EF of energy consumption is straightforward, since it quantifies a part of EF through CF calculations, EF of water utilisation and EF of waste generation have controversial assumptions because of not allocating direct land categories by standard EF methodology, to measure their impacts"*. Some respondents highlighted difficulty to obtain conversion factors for EF calculations as a barrier. Expressing his views, B2 added, *"Yield factors and equivalence factors are not readily available in the local context and we have to download* *international reports like National Footprint Accounts to obtain this data. Without having conversion factors, EF calculations cannot be done in terms of global hectare units"*. Unavailability of waste water treatment in some factories is another barrier highlighted by some respondents. C2 emphasised *"Not all the factories treat waste water at their premises. So they cannot account for EF of water utilisation by quantifying energy consumed in waste water treatment"*. Therefore, unavailability of waste water treatment in some factories, is a barrier to calculate EF of water utilisation. Lack of data to calculate EF of waste generation in some factories, insufficient commitment of top management to calculate EF, lack of promotion of the EF concept by responsible authorities and reluctance of footprint calculating personnel to calculate many footprints are the other barriers highlighted by the respondents. These barriers are listed as follows:

- Difficulty of understanding underlying assumptions of EF of water utilisation and EF of waste generation
- Difficulty to obtain conversion factors for EF calculations
- Unavailability of waste water treatment in some factories
- Insufficient commitment of top management to calculate EF
- Lack of data to calculate EF of waste generation in some factories
- Lack of promotion of EF concept by responsible authorities
- Reluctance of footprint calculating personnel to calculate many footprints

4.3. STRATEGIES TO MINIMISE BARRIERS IN APPLYING ECOLOGICAL FOOTPRINT IN APPAREL SECTOR BUILT ENVIRONMENTS IN SRI LANKA

Strategies were proposed based on the opinions of respondents to minimise aforementioned barriers. Providing training and awareness on EF calculation at factory level, raising awareness on calculating EF of water utilisation and EF of waste generation are two of the strategies proposed by the respondents. Since calculation of EF of water utilisation and EF of waste generation contain certain assumptions, according to B3, *"Providing awareness about the EF concept throughout the apparel sector is the best way to address controversial assumptions"*. A3 commented on the importance of conducting training programmes as, *"These should specially focus non-executive employees who involve in current footprint calculation process, because they find it difficult to understand these concepts, without proper guidance"*. Many respondents pointed out that aforementioned two strategies can contribute to communicate the importance of EF calculations and encourage factories on treating waste water and managing waste. Some respondents suggested that implementing waste water treatment and waste management in factories should be mandated. Appointing a designated employee for footprint calculations at factory level is another strategy. C2 proposed, *"A job title for a Sustainability Officer should be created at factory level to calculate all these footprints and oversee the footprint calculation process"*. Convincing top management about the importance of EF calculation, maintaining records of conversion factors in a centralised database for apparel sector and implementing programmes to increase recognition for factories which calculate EF are the strategies which should be implemented as proposed by the respondents. These strategies are listed as follows:

- Providing training and awareness on applicability of EF
- Raising awareness on calculating EF of water utilisation and EF of waste generation
- Appointing a designated employee for footprint calculations at factory level
- Implementing waste water treatment and waste management in factories
- Convincing top management about the importance of EF calculation
- Maintaining records of conversion factors in a centralised database for apparel sector
- Implementing programmes to increase recognition for factories which calculate EF

5. CONCLUSIONS AND RECOMMENDATIONS

With the rising adverse impacts on environment, numerous indicators have been developed to evaluate environmental sustainability. Due to its wide scope, EF plays a major role in the context of environmental sustainability since it can be used as an indicator to quantify resource consumption and waste generation. Findings from the case studies proved that EF is partially practiced in apparel manufacturing factories which calculate CF and WF, although it is not quantified in terms of biologically productive land categories. It was deduced that EF is applicable to evaluate environmental sustainability in apparel sector in Sri Lanka. Barriers which constrain the successful applicability of EF were determined by the opinions of respondents. Accordingly, difficulty of understanding underlying assumptions of EF of water utilisation and EF of waste generation was identified as the major barrier to apply EF to evaluate environmental sustainability in apparel sector built environments in Sri Lanka. Strategies were proposed by the respondents to overcome these barriers. Providing training and awareness on EF calculation at factory level, raising awareness on calculating EF of water utilisation and EF of waste generation, appointing a designated employee for footprint calculations at factory level are some of the strategies. Outcomes of this research will be beneficial for the industry practitioners of apparel industry, for improving the environmental performance of Sri Lankan apparel sector built environments.

6. REFERENCES

Borucke, M., Moore, D., Cranston, G., Gracey, K., Iha, K., Larson, J., Lazarus, E., Morales, J.C., Wackernagel, M. and Galli, A., 2013. Accounting for demand and supply of the biosphere's regenerative capacity: The National Footprint Accounts' underlying methodology and framework. *Ecological Indicators*, 24, 518-533.

Butnariu, A. and Avasilcai, S., 2014. Research on the Possibility to Apply Ecological Footprint as Environmental Performance Indicator for the Textile Industry. *Procedia - Social and Behavioral Sciences*, 124, 344-350.

Čuček, L., Klemeš, J.J. and Kravanja, Z., 2012. A review of footprint analysis tools for monitoring impacts on sustainability. *Journal of Cleaner Production*, 34, 9-20.

Čuček, L., Klemeš, J., Varbanov, P. and Kravanja, Z., 2015. Significance of environmental footprints for evaluating sustainability and security of development. *Clean Technologies and Environmental Policy*, 17(8), 2125-2141.

Dawson, C., 2002. *A practical guide to research methods: A user-friendly manual for mastering research techniques and projects.* 3rd ed. Oxford: How To Books.

Figge, L., Oebels, K. and Offermans, A., 2016. The effects of globalization on Ecological Footprints: an empirical analysis. Environment, *Development and Sustainability*, 19(3), 863–876

Galli, A., Kitzes, J., Wermer, P., Wackernagel, M., Niccolucci, V. and Tiezzi, E., 2007. An exploration of the mathematics behind the ecological footprint. *International Journal of Ecodynamics*, 2(4), 250-257.

Galli, A., Wiedmann, T., Ercin, E., Knoblauch, D., Ewing, B. and Giljum, S., 2012. Integrating Ecological, Carbon and Water footprint into a "Footprint Family" of indicators: Definition and role in tracking human pressure on the planet. *Ecological Indicators*, 16, 100-112.

Galli, A., Weinzettel, J., Cranston, G. and Ercin, E., 2013. A Footprint Family extended MRIO model to support Europe's transition to a One Planet Economy. *Science of the Total Environment,* 461-462, 813-818.

Global Footprint Network., 2017. Available from: http://www.footprintnetwork.org/en/index.php/GFN/page/glossary/ [Accessed 15 January 2017]

González-Vallejo, P., Marrero, M. and Solís-Guzmán, J., 2015. The ecological footprint of dwelling construction in Spain. *Ecological Indicators*, 52, 75-84.

Herath, L., 2015. *Estimating an organisational water footprint in apparel industry: A case study of MAS Linea Aqua Sri Lanka*. Master's thesis. University of Colombo.

Herva, M., Franco, A., Ferreiro, S., Álvarez, A. and Roca, E., 2008. An approach for the application of the Ecological Footprint as environmental indicator in the textile sector. *Journal of Hazardous Materials*, 156(1-3), 478-487.

Hoekstra, A.Y., 2009. Human appropriation of natural capital: A comparison of ecological footprint and water footprint analysis. *Ecological Economics*, 68(7), 1963-1974.

Jaganathan, V., Cherurveettil, P., Chellasamy, A. and Premapriya, M. S., 2014. Environmental pollution risk analysis and management in textile industry: A preventive mechanism. *European Scientific Journal*, 2, 323-329

Kitzes, J., Peller, A., Goldfinger, S. and Wackernagel, M., 2007. Current Methods for Calculating National Ecological Footprint Accounts. *Science for Environment and Sustainable Society*, 4(1). 1-9

Martínez-Rocamora, A., Solís-Guzmán, J. and Marrero, M., 2016. Toward the Ecological Footprint of the use and maintenance phase of buildings: Utility consumption and cleaning tasks. *Ecological Indicators*, 69, 66-77.

Moldan, B., Janoušková, S. and Hák, T., 2012. How to understand and measure environmental sustainability: Indicators and targets. *Ecological Indicators*, 17, 4-13.

Munasinghe, M., Jayasinghe, P., Ralapanawe, V. and Gajanayake, A., 2016. Supply/value chain analysis of carbon and energy footprint of garment manufacturing in Sri Lanka. *Sustainable Production and Consumption,* 5, 51-64.

Niinimäki, K. and Hassi, L., 2011. Emerging design strategies in sustainable production and consumption of textiles and clothing. *Journal of Cleaner Production,* 19(16), 1876-1883.

Rees, W. and Wackernagel, M., 1996. Urban ecological footprints: Why cities cannot be sustainable—And why they are a key to sustainability. *Environmental Impact Assessment Review,* 16(4-6), 223-248.

Saunders, M. N., Lewis, P. and Thornhill, A., 2009. *Research methods for business students*. 5th ed.. Harlow, England: Prentice Hall.

Tian, M., Gao, J., Zheng, Z. and Yang, Z., 2012. The Study on the Ecological Footprint of Rural Solid Waste Disposal-example in Yuhong District of Shenyang. *Procedia Environmental Sciences*, 16, 95-101.

Toth, G. and Szigeti, C., 2016. The historical ecological footprint: From over-population to over-consumption. *Ecological Indicators,* 60, 283-291.

Van den Bergh, J. and Grazi, F., 2013. Ecological Footprint Policy? Land Use as an Environmental Indicator. *Journal of Industrial Ecology,* 18(1), 10-19.

Wiedmann, T. and Barrett, J., 2010. A Review of the Ecological Footprint Indicator—Perceptions and Methods. *Sustainability*, 2(6), 1645-1693.

Wood, R. and Lenzen, M., 2003. An Application of a Modified Ecological Footprint Method and Structural Path Analysis in a Comparative Institutional Study. *Local Environment*, 8(4), 365-386.

Yin, R. K., 2011. *Qualitative research from start to finish*. New York: The Guilford Press.

EMBRACING ADAPTIVE RE-USE OF BUILDINGS: THE CASE OF SRI LANKA

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ABSTRACT

Because of land scarcity, the ever-increasing demand for new constructions has caused a grave crisis in the construction industry. This has led to the inevitable demolition of the existing building stock. In many cities, there are malfunctioning or abandoned ancient buildings situated mostly in commercially significant locations. These buildings which narrate the evolution of their cities have become important, either for historical reasons or because of their cultural heritage. For any country, its existing building stock will be of significant economic, physical and socio-cultural value. Adaptive Re-use of Buildings (ARB) is the best option available to make optimum use of the existing stock. Developing countries still have not appropriately embraced this concept as in developed countries. Thus, the objectives of this research were to identify the key parameters, benefits, barriers and challenges related to ARB in Sri Lanka. A qualitative research approach was adopted to achieve this aim by conducting expert interviews on five case studies and semi-structured interviews involving 15 local expert professionals already practicing ARB to validate the expert interview findings. Content analysis was used to analyze the findings. Physical, social and economic considerations, building codes, regulations, lack of awareness on adaptive re-use opportunities and the scarcity of material and skilled tradesmen were identified to be the most frequently encountered barriers among which were further categorized under five major groups.

Keywords: *Adaptiveness; Adaptive Re-use of Buildings (ARB); Barriers and Challenges; Existing Building Stock; Socio-Cultural and Environmental Benefits.*

1. INTRODUCTION

The increasing demand for new constructions along with the scarcity of land has led to the demolition of existing buildings (Hakkinen, 2007; Petersdorff *et al*., 2004). The authors emphasise that demolition is actually required for only 0.5-1.0 % of the existing building stock as the rest have 30-50 more years left of their life spans. Reuse of these buildings would fulfill current building needs. According to Langston (2008), older buildings which have made a significant contribution to the historical and cultural aspects of their countries are probably situated in areas of high commercial value and the Adaptive Re-Use of Buildings (ARB) can play a pivotal role in the regeneration of the built environment by preserving the prestige of historic buildings.

According to Latham (2000), adaptive re-use is a process that upgrades and enhances the performance of buildings to meet modern standards and changing user requirements while the original building is retained as much as possible. Johnson (1996) emphasizes that even when buildings have been designed to last long, they can become unfit for the originally designed purpose due to obsolescence and redundancy due to change in the demand for their services or lack of continuous maintenance. This building redundancy has a large impact on the existing building stock. In developed countries, strategies such as, “adaptive re-use” (Kincaid, 2000) which have shown positive trends have been adopted to mitigate such impacts. The situation in developing countries in this regard has so far not been analyzed. The decision to demolish historical buildings is taken considering their low economic values while ignoring their socio-cultural and historical importance (Smith, 2005; Wood and Muncaster, 2012). The cost effectiveness, rising energy costs and the high cost of new constructions make clients to opt for adaptive re-use of the existing building stock (Douglas, 2006; Kohler and Yang, 2007).

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Unlike developing countries, developed countries focus on identifying effective methods and opportunities of designing new buildings to cater to ARB and the sustenance of the existing stock to cater to the future market (Sheffer and Levitt, 2010). Developing countries too need to explore such avenues to ensure sustainable investment on the existing building stock, which at present is mostly under-used or abandoned. Such trends can yield numerous socio-cultural and environmental benefits to the respective communities. O'Donnell (2004) argues that an adapted building cannot compete with a new building as far as its performance is concerned, and that this gap needs to be balanced against social gains. This provides an opportunity to re-life an existing building and optimises its whole lifecycle cost. In the developing countries, such opportunities have not yet been identified.

ARB is common in developed countries where there is restoration of historically important buildings preserving their historical value towards using them for greater causes. On the contrary, in the developing countries, ARB has not yet become popular in the absence of proper research done on it. Hence, this research became necessary to identify the barriers and challenges related to the embracing of ARB in developing countries with Sri Lanka as an example. The parameters influencing the adoption of ARB, its benefits, barriers and challenges of its implementation identified in the literature for developed countries cannot be directly applied to Sri Lanka because of the socio-cultural, environmental, legal, geological and economic disparities. Although the building stock in Sri Lanka is comparatively small, it has evolved very much with time. Hence, the systematic identification of the barriers and challenges related to the embracing of ARB in Sri Lanka becomes a critical need to make the construction industry practice ARB knowledgeably preserving the evolution of the existing building stock.

The aim of this research was to analyze the barriers and challenges related to the embracing of Adaptive Re-use of Buildings in Sri Lanka. The objectives were identified as (a) To identify the key parameters influencing adaptiveness of the existing building stock in Sri Lanka, (b) To identify the benefits of ARB in Sri Lanka and (c) To validate the identified barriers and challenges of ARB in the context of Sri Lanka.

2. LITERATURE FINDINGS

2.1. CONCEPT OF RE-USE AND EMBODIED ENERGY IN THE EXISTING BUILDING STOCK

A key decision the owners of an old building have to make is whether to reuse it or demolish it. In the construction industry today, the demolition of existing buildings is considered as a waste of energy and material (Department of the Environment and Heritage [DEH], 2004). Due to land scarcity, the demolition of buildings ignoring its environmental consequences had been the choice in the past as against refurbishment and re-use (Shipley *et al*., 2006). Graham (2003) wants to limit the expansion of the existing building stock to conserve its embodied energy. Binder (2003) claims that a considerable amount of embodied energy is packed in the existing building stock and that building re-use is important to mitigate its waste. The re-use of built assets is environmentally sustainable as it retains the embodied energy of the original building (Treloar *et al*., 2001; Treloar *et al*., 2000) and ARB is a dynamic alternative that will minimize such issues (Kincaid, 2000).

2.2. ADAPTIVE RE-USE OF BUILDINGS

Any work on a building that will change its capacity, function or performance can be identified as building adaption (Douglas, 2006). Adaptive reuse has been derived from building adaptation (Latham, 2000) and is defined as a process of upgrading and enhancing the performance of a building to meet modern standards and changing user requirements while retaining the original building as much as possible. DEH (2004) describes ARB as a process that transforms a disused or ineffective item into a new item that can be used for a different purpose (p.3). Latham (2000) suggests that adaptive reuse should use the hidden qualities and embodied energy of the original building in a sustainable and dynamic manner to perform afresh. Latham's (2000) definition on ARB was chosen for this study as it covers the main aims of ARB, namely the retention of the character and the architecture of the original buildings while reusing them. Figure 1 presents ARB in relation to other alternatives as determined by Kincaid (2002).Ellison and Sayce (2007) emphasize that adaption can take place as "within use" or as "across use". For example, if when an office is adapted it continues to remain as an office, it will be called a "within use adaptation" and if the adapted office is used for a different purpose like for a residence, it will be called an "across use adaptation".

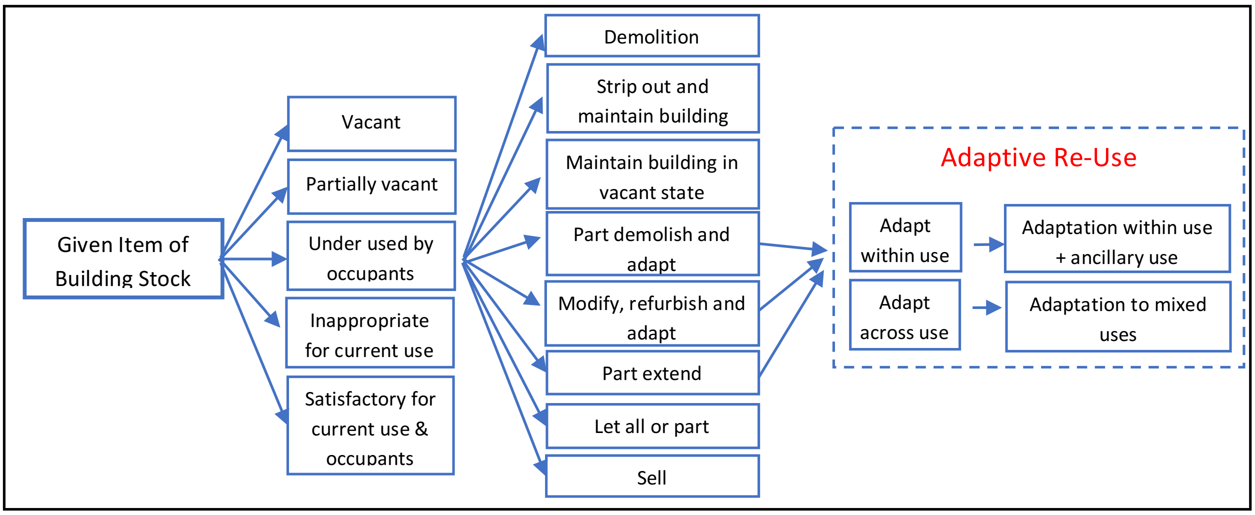

Figure 1: Position of Adaptive Re-Use Among Other Alternatives
(Source : Adapted from Kincaid, 2002, p.12)

2.3. PARAMETERS AND CHARACTERISTICS INFLUENCING THE ADAPTIVE RE-USE OF BUILDINGS

There are several building parameters that influence ARB both directly and indirectly and which have been proved through research studies conducted by Manewa, *et al*. (2016), Ball (2002), Wilkinson (2014) and Snyder (2005). Table 1 presents a summary of the most influential parameters found.

Table 1: Parameters Influencing the Adaptiveness of Buildings

Parameters	**Identified Research Study**
Age	Ball (2002, 1999)
Internal Space/ Area	Manewa *et al*. (2016); Larssen and Bjorbery (2004)
Flexibility available for different users	Gann and Barlow (1996)
Heritage Value	Snyder (2005); Ball (2002)
Vertical Circulation	Rawlinson and Harrison (2009); Larssen and Bjorbery (2004)
Fire/ Safety Design	Arge (2005)
Building Envelope and External Façade	Rawlinson and Harrison (2009); Arge (2005); Gann and Barlow (1996)
Building Width	Gann and Barlow (1996)
Technical Span and Services	Wilkinson (2014); Snyder (2005); Gann and Barlow (1996)
Location/ Site Conditions	Douglas (2006); Kincaid (2002); Larssen and Bjorbery (2004)
HVAC Distribution	Rawlinson and Harrison (2009); Arge (2005); Gann and Barlow (1996)
Building Condition	Snyder (2005); Swallow (1997); Baird *et al*. 1996)
Floor to Ceiling Height/ Story Height	Wilkinson (2014); Rawlinson and Harrison (2009); Arge (2005);
Structural Design	Rawlinson and Harrison (2009); Larssen and Bjorbery (2004)
Accessibility/ Proximity	Ball (2002); Ellison and Sayce (2007); Remoy and van der Voordt (2007); Gann and Barlow (1996);

Each parameter has its own risks and advantages. The parameters need to be identified, assessed and managed properly to enable the best decision (Wilkinson *et al*., 2009). ARB provides numerous benefits to both owners and occupants of buildings.

2.4. *BENEFITS OF ADAPTIVE RE-USE OF BUILDINGS*

Bullen (2007) and Dyson *et al*., (2016) categorize the benefits of ARB into three interactive groups, namely economic benefits, social benefits and environmental benefits.

***Economic Benefits*:** Shipley *et al*. (2006) indicate that the average cost saving possible from the adaptive re-use of a building as compared to a new construction is approximately 10-12%. Many research work indicate that it is often less costly to adapt a building rather than constructing a new building (Ball, 2002; Bullen, 2007; Campbell, 1996; Douglas, 2006; Shipley *et al*., 2006). In Hong Kong, a 9.8% increment in property values was noticed as resulting from ARB (Chau *et al*, 2003).

***Environmental Benefits*:** Itard and Klunder (2007); Bullen (2007) and Johnstone (1995) consider demolition as not environmentally friendly. While studying a renovation project, they have observed that building adaptation consumed fewer materials and generated less waste and energy compared to demolition and reconstruction. Ball (2002) has observed in a UK study that environmental and social benefits can influence an ARB decision favorably in spite of economic costs. The negative impacts of pollution caused by construction can cause the degradation of habitats and bio-diversity, altered eco-systems, reduced water and air quality and the spread of infections that affect both animals and humans (Koren and Buttler, 2006).

***Social Benefits*:** Bullen (2007) suggests a broader recognition for ARB as it forms a part of urban regeneration which helps future generations to yield benefits from building protection (DEH, 2004). Adaptive reuse is identified as a strategy for extending the physical and social function of a building to give it a new purpose while preserving its historic legacy (DEH, 2004; Latham, 2000; Wilkinson *et al*., 2009). Remoy and Wilkinson, (2012) stated that vacant or obsolete buildings can lead to anti-social activities which can be prevented through ARB. ARB investments can contribute significantly to boost the living standards of communities of neglected areas (Ball, 2002, 1999; Langston and Shen, 2007).

2.5. *BARRIERS AND CHALLENGES: ADAPTIVE RE-USE OF BUILDINGS IN DEVELOPED COUNTRIES*

Bullen (2007) believes that there is a wide range of barriers and opportunities for adaptive reuse and further that economic factors are a common concern with regard to barriers. For example, the cost of adaptive reuse will be difficult to estimate. Moreover, he insists on the importance of awareness on ARB that will help to acknowledge its immeasurable social and environmental benefits. Common barriers and challenges as found from the literature are summarized in Table 2.

Table 2: Barriers and Challenges Common in the Adaptive Re-Use of Buildings

Barriers and Challenges related to ARB	Brief Description	Identified Research Study
Physical barriers	Existing structural and walls, floor; column layouts	Bruce *et al*. (2015); Bullen and Love (2011); Bullen (2007); Reyers and Mansfield (2001)
Economic restrictions	Conservation costs (Direct or Indirect)	Bullen (2007); Douglas (2006); O'Donnell (2004); Reyers and Mansfield (2001); Shipley *et al*. (2006); Yung and Chan (2012)
Social concerns	Imperceptible non-economic values	DEH (2004); Yung and Chan (2012)
Building codes and regulations/ legal constraints	Current planning requirements, building codes and regulations; conservation	Bruce *et al*. (2015); Bullen and Love (2011); Bullen (2007); Douglas (2006); Shipley *et al*. (2006); Wilkinson *et al*. (2009)
Lack of material and skilled tradesmen	Availability of experts and material matching to the existing crafts	Bullen and Love (2011); Douglas (2006); Remoy and van der Voordt (2007); Reyers and Mansfield (2001)
Limited response to sustainability agenda	Reluctance of the property owners towards transformation to sustainable methods	Ellison and Sayce (2007); O'Donnell (2004)
Complexity and technical challenges	Innovative technical and refurbishment solutions for heritage buildings	Bruce *et al*. (2015); Bullen and Love (2011); Ball (1999); Shipley *et al*. (2006)
Maintenance challenges	Physical defects and deteriorations causing maintenance issues	Bullen and Love (2011); Remoy and van der Voordt (2007); Bullen (2007); O'Donnell (2004)

Barriers and Challenges related to ARB	Brief Description	Identified Research Study
Lack of awareness on ARB opportunities	False and negative beliefs with less awareness on ARB	Bullen and Love (2010); Remoy and van der Voordt; (2007); Bullen (2007; 2004); Shipley *et al*.; (2006)
Financial and technical perceptions	The notion that demolition is the only avenue to get a sensible profit as ARB is considered too expensive	Bruce *et al*. (2015); Bullen and Love (2011); Shipley *et al*. (2006); Yung and Chan (2012),
Commercial risk and uncertainty	Lengthy and difficult renovation or reuse often leads to reduced profits	Bruce *et al*. (2015); Bullen and Love (2011); Shipley *et al*. (2006),
Delayed constructions with higher remediation costs	Corruption due to the use of hazardous materials in buildings that causes extra costs; time delays	Bruce *et al*. (2015); Bullen and Love (2011); Bullen (2007); Wilkinson *et al*. (2009)
Imprecision of available drawings and information	Heritage buildings are lacking correct information/ drawings	Remoy and van der Voordt (2007); Reyers and Mansfield (2001)
Classification (Zoning) changes	Scope and classification changes of buildings that need building code and zoning compliance	Conejos *et al*. (2016); Bullen and Love (2011); Reyers and Mansfield (2001)
Inactive production and development criteria	Development criteria of cities pose challenges to urban regeneration	Conejos *et al*. (2016); Bullen and Love (2011);
Creative value compared to redevelopment	Finishing related creativity and outer appearance of the building	Bullen (2007; 2004)

Lack of awareness has caused misunderstandings about safety and health among people, high maintenance costs and commercial uncertainty on investments (Bullen, 2007; Bullen and Love, 2010; Remoy and van der Voordt, 2007; Shipley *et al*., 2006). Bullen (2004) claims that many buildings have some potential for adaption although the environmental impact could be significant. Hence, to optimize ARB, it is necessary to make a proper assessment of its barriers and challenges.

3. RESEARCH METHODOLOGY

Brikci and Green (2007) claim that the best method for collecting opinions and facts from people on their experience and behavior is the qualitative research approach. Willis (2007) suggests proceeding with qualitative information when an in-depth analysis is required. Thus, the qualitative research approach was used in this research. In Sri Lanka, there are only a few projects that have used Adaptive Reuse of Buildings, which is yet to gain popularity in the country. The number of professionals who have had exposure to ARB in Sri Lanka is thus limited. Data collection was carried out through expert interviews, in depth case studies and physical observations. The expert interviews were with three professionals who were practicing ARB successfully and passionately in Sri Lanka having over 20 years of overall professional experience out of which over 15 years were in ARB. Five substantially significant recently completed ARB projects (see Table 3) located in Colombo area and Galle were selected for the case studies. The case studies were required to validate the expert interview findings. During each case study, semi-structured interviews to collect data were held with the project architect, quantity surveyor, and structural engineer, all of whom had over 12 years of professional experience. Interview findings were analysed using content analysis to arrive at the conclusions.

Table 3: Summarised Details of the Case Studies

Description	Case 1	Case 2	Case 3	Case 4	Case 5
Currently Adapted Use of Building	Shopping and Restaurant Complex	Luxury Boutique Hotel	Technological Park Building Complex	Saloon and Spa	Shopping and Restaurant Complex
Previous use (Before Adaption)	Office complex of an asylum	Dutch residence of a merchant	Colonial warehouse	Colonial warehouse	Colonial hospital
Approx. Cost	US$ 3.61 Mn	US$ 1.64 Mn	US$ 7 Mn	US$ 0.49 Mn	US$ 1.31 Mn
Location	Colombo 07	Galle Fort	Colombo 10	Colombo 02	Colombo Fort
Employer Type	Public	Private	Public + Private	Private	Public

4. FINDINGS AND ANALYSIS

4.1. KEY PARAMETERS INFLUENCING ADAPTIVENESS OF EXISTING BUILDINGS IN SRI LANKA

Expert interviewees considered building characteristics and parameters as factors to be considered critically when deciding on the adaptive re-use of buildings. The key parameters influencing the adaptiveness of existing buildings in Sri Lanka were identified from the expert interviews. Parameters such as age; internal space/ area; building condition; floor to ceiling height/ story height; building envelope and external facade; technical span and services; vertical circulation; location/ site conditions; structural design; accessibility/ proximity; flexibility for different uses; heritage value, influence mostly the adaptiveness of the existing building stock of Sri Lanka. Fire/ safety design and HVAC distribution parameters were omitted (see Table1) based on case study validations.

4.2. BENEFITS OF ADAPTIVE RE-USE OF BUILDINGS IN SRI LANKA

ARB can provide many opportunities for developing countries if proper investments could be made by identifying the scope, method and market for adaptability. The expert interviews indicated their possible social, environmental and economic benefits if used in Sri Lanka (Table 4).

Table 4: Benefits of Adaptive Re-Use of Buildings in Sri Lanka

	Benefits of Adaptive Re-use of Buildings	**Found in Literature**	**Applicability to Sri Lanka**	**Validated by (out of 5 cases)**
	Social Benefits			
01.	A good alternative to retain the embodied cultural and social capital of important buildings	✓	✓	5
02.	Fulfils a new purpose while preserving the historical legacy	✓	✓	5
03.	Prevents antisocial activities in the abandoned buildings	✓	✓	4
04.	Boosts the living standards of the people in neglected areas	✓	✓	5
05.	Creates additional jobs in the neglected areas	✓	✓	4
06.	Provides a glimpse of the past about the characteristics and identities of certain areas	✓	✓	5
07.	Indicates city evolution	✓	✓	5
08.	***Sense of belonging felt by the people***		✓	4
	Environmental Benefits			
09.	Nil or less demolition	✓	✓	5
10.	Consumes fewer materials and provides for the reuse of materials	✓	✓	4
11.	Generates less waste and energy than demolition and reconstruction	✓	✓	4
12.	Causes less environmental pollution during construction	✓	✓	5
13.	Preserves embodied energy of the original buildings	✓	✓	4
14.	Leads to sustainability in the built environment	✓	✓	3
15.	***Ensures cleanliness and good appearance of the city***		✓	5
	Economic Benefits			
16.	Lower costs compared to those related to putting up a new building	✓	✓	3
17.	Higher profits made from higher plot ratios of older property	✓	✓	3
18.	Increased property values after the adaption	✓	✓	5
19.	Extension of building's life cycle	✓	✓	4
20.	Existence of structural components	✓	✓	4
21.	Shorter contract and construction periods	✓	✓	5
22.	***Commercial initiatives in abandoned buildings generate revenue***		✓	5
23.	***Avoidance of demolition and its related costs***		✓	5
24.	***Tourist attractions***		✓	5
25.	***Willingness of companies to move into adapted buildings to demonstrate their passion and identity***		✓	5

The benefits indicated in bold italics (see Table 4) are found specific to Sri Lanka. The sense of belonging the people will have and the cleanliness and good appearance of the cities would be socially and environmentally beneficial. As a famous tourist destination, Sri Lanka will specifically benefit by attracting tourists to the adaptively re-used historic buildings. This will generate revenue both directly and indirectly to the associated communities and meet building operational costs. Simultaneously, leading Sri Lankan companies would opt to occupy the adapted buildings to enhance their local identities and provide their employees with a mind soothing working environment that will lead to improved productivity.

4.3. VALIDATION OF THE BARRIERS AND CHALLENGES FACED IN SRI LANKA

Although, ARB is being practiced in the construction industry to some extent in Sri Lanka, the expert interviewees highlighted that it is not being practiced at its best. They further emphasized that several barriers and challenges hinder the proper functioning of ARB in the country. These barriers and challenges were validated using the case studies and grouped under five categories, namely as social; environmental; economic; legal-regulatory and physical, technical and other barriers (See Table 5).

Table 5: Validation of the Identified Barriers and Challenges in the Context of Sri Lanka

	Barriers and Challenges of ARB in Sri Lanka	**Expert Interview Findings**	**Validated from Case Studies**				
			Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**
	Social Barriers and Challenges						
01.	Lack of awareness on ARB opportunities and benefits	✓	✓		✓		✓
02.	Social upheavals against changing of the genuine heritage property	✓		✓			✓
03.	Notion that demolition is the best alternative since ARB is costly	✓	✓	✓	✓	✓	
04.	Social reluctance due to the building's previous usage (asylums etc.)	✓	✓				
05.	***Social reluctance for changing day to day activities in the property***	✓		✓	✓	✓	
06.	***Traditional practice being preservation of buildings rather than their reuse***	✓	✓	✓			✓
	Environmental Barriers and Challenges						
07.	Inadequate responses to sustainability criteria	✓			✓	✓	✓
08.	***Adverse weather conditions experienced halfway during renovation***	✓		✓			✓
	Economic Barriers and Challenges						
09.	Fund/ capital allocation	✓	✓		✓	✓	✓
10.	High maintenance and repair costs	✓	✓				✓
11.	Financial uncertainty/risk on the investment	✓		✓	✓	✓	✓
12.	***Higher opportunity costs***	✓	✓	✓	✓	✓	✓
	Legal and Regulatory Barriers and Challenges						
13.	Adherence to existing building codes	✓	✓	✓	✓	✓	✓
14.	Zoning (Classification) restrictions	✓	✓	✓			
15.	Health and safety requirements of the authorities	✓	✓	✓	✓	✓	✓
16.	***Special legal acts -Sri Lanka archeological sites act***	✓		✓			✓
17.	***Unclear deeds and ownerships***	✓					
	Physical, Technical and Other Barriers and Challenges						
18.	Restrictions due to structural system layouts	✓	✓	✓			✓
19.	Scarcity of required material and skilled tradesmen	✓		✓	✓		✓
20.	Need for innovative solutions for heritage/ historic buildings	✓	✓	✓		✓	✓
21.	Unavailability of structural and services drawings	✓		✓	✓	✓	✓
22.	***Insufficient space available to accommodate modern HVAC and fire safety services***	✓	✓		✓	✓	✓
23.	***Lack of complex technologies and skilled technicians***	✓	✓	✓			✓
24.	***Maintenance issues due to physical defects after adaption***	✓	✓			✓	

The barriers indicated in bold italics in Table 5 above are specific to Sri Lanka. In the cross case analysis, the lack of awareness on ARB opportunities and benefits; the notion that demolition is the best alternative, ARB being expensive; *Social reluctance for changing day to day activities in the ARB potential property; Preservation of buildings being the traditional method rather than the reuse of building*s; Inadequate response to sustainability criteria, Fund/ capital allocation; Financial uncertainty/ risk on the investment; Higher opportunity costs; Adherence to current building codes; Health and safety requirements of the authorities; *Special legal acts like Sri Lanka archaeological sites act; Restrictions due to structural system layouts*; Scarcity of required material and skilled tradesmen; Need for innovative solutions for proper adaption of heritage/ historic buildings; Unavailability of structural and services drawings; *Insufficient space available to accommodate modern HVAC and fire safety services; Lack of complex technology and skilled technicians*, were derived as most significant from the validation process. Moreover, the expert interviewees revealed that, in developing countries the economic barriers are overruling most of the other concerns, specifically in private sector initiated ARB projects. They further added that, when it comes to public sector ARB projects the government rather concerns on social and environmental benefits over economic barriers unless that significantly make a negative impact on the country's economy.

5. CONCLUSIONS

The key building characteristics influencing ARB, benefits of ARB and barriers and challenges related to ARB, relevant to developing countries were identified in the context of Sri Lanka for a more effective and systematic implementation of ARB. The relevance of parameters influencing ARB were proved and the benefits and opportunities of ARB for Sri Lanka were validated and grouped under social, environmental and economic aspects. The barriers and challenges related to ARB implementation in Sri Lanka were identified and validated through five recent case studies that were significant. The barriers and challenges that obstruct the successful adoption of ARB in Sri Lanka were categorized under Social; Environmental; Economic; Legal-Regulatory; and Physical, Technical-Other; barriers and challenges, to make it easy to address their root causes. The benefits as well as the barriers and challenges specifically observed in Sri Lanka were identified in Sections 4.2 and 4.3 respectively.

6. RECOMMENDATIONS

The following improvements could be done to make ARB in Sri Lanka more effective and systematic:

- Government Involvement: To make an impressive boost to ARB related decision making;
- Incentives and Tax concessions: To directly influence people to adopt ARB
- Incorporation of ARB into subject areas in related curricula: To teach ARB concepts to students of related subject areas to educate them on the true value and the importance of ARB
- Continuing Professional Development (CPD): To enlighten industry professionals about ARB and on the new trends and technologies of ARB

The above recommendations would allow Sri Lanka and other developing countries to reap optimum benefits of ARB practice and support their community development, enhancing living standards as well.

7. REFERENCES

Arge, K., 2005, Adaptable Office Buildings: Theory and Practice. *Facilities*, 23(3), 119-127.

Baird, G., Gray, J., Isaacs, N., Kernohan, D. & McIndoe, G., 1996, *Building Evaluation Techniques*, McGraw Hill, Wellington.

Ball, R.M.,1999, Developers, Regeneration and Sustainability Issues in the Reuse of Vacant Buildings. *Building Research and Information*, 27(3), 140-148.

Ball, R.M., 2002, Re-use Potential and Vacant Industrial; Premises: Revisiting the Regeneration Issue in Stoke-on-trent. *Journal of Property Research*, 19(2), 93-110.

Binder, M., 2003, *Adaptive Reuse and Sustainable Design: A Holistic Approach for Abandoned Industrial Buildings*. Master of Architecture, The School of Architecture and Interior Design, University of Cincinnati, OH. Retrieved from http://internationalinventjournals.org/journals/IIJASS

Brikci, N. and Green, J., 2007, *A Guide to Using Qualitative Research Methodology*. London: Medecins Sans Frontieres

Bruce, T., Zuo, J., Rameezdeen, R. and Pullen, S., 2015, Factors influencing the retrofitting of existing office buildings using Adelaide, South Australia as a case study. *Structural Survey,* 33 (2), 150–166.

Bullen, P.A., 2007, Adaptive Reuse and Sustainability of Commercial Buildings. *Facilities*, 25(1/2), 20-31.

Bullen, P.A., 2004, Sustainable Adaptive reuse of the Existing Building Stock in Western Australia. In Khosrowshahi F., ed. *20th Annual ARCOM Conference,* 1-3 September 2004, Heriot Watt University-Volume 2, UK: Association of Researchers in Construction Management, 1387-1397.

Bullen, P.A. and Love, P.E.D., 2011, Factors influencing the adaptive re-use of buildings. *Journal of Engineering, Design and Technology*, 9(1), 32 - 46.

Bullen, P.A. and Love, P.E.D., 2010, The Rhetoric of Adaptive Reuse or Reality of Demolition: Views from the Field. *Cities*, 27(4), 215-224.

Campbell, J., 1996, Is Your Building a Candidate for Adaptive Reuse?. *Journal of Property Management,* 61(1), 26-30.

Chau, K.W., Leung, A.Y.T., Yin, C.Y. and Wong, S.K., 2003, Estimating the Value Enhancement Effects of Refurbishment. *Facilities,* 21(1), 13-19.

Conejos, S., Langston, C., Chan, E. H. W. and Chew M. Y. L., 2016, Governance of Heritage Buildings: Australian Regulatory Barriers to Adaptive Reuse. *Building Research and Information*, 1-13.

Department of the Environment and Heritage (DEH), 2004, *Adaptive Reuse: Preserving Our Past Building Our Future*. Canberra: Australian Government.

Douglas, J, 2006, *Building Adaptation.* 2nd ed., MA: Butterworth Heinemann, Oxford.

Dyson, K., Matthews, J. and Love, P.E.D., 2016, Critical Success Factors of Adapting Heritage Buildings: An Exploratory Study. *Built Environment Project and Asset Management,* 6(1), 44- 57.

Ellison, L. and Sayce, S., 2007, Assessing Sustainability in the Existing Commercial Property Stock. *Property Management,* 25(3), 287-304.

Gann, D.M. and Barlow, J., 1996, Flexibility in Building Use: The Technical Feasibility of Converting Redundant Offices Into Flats. *Construction Management and Economics*, 14(1), 55-66.

Graham, P., 2003, *Building Ecology*. United Kingdom, Oxford: Blackwell Science.

Hakkinen, T., 2007, Assessment of Indicators for Sustainable Urban Construction. *Civil Engineering and Environmental Systems*, 24(4), 247-259.

Itard, L. and Klunder, G., 2007, Comparing Environmental Impacts of Renovated Housing Stock with New Construction. *Building Research and Information*, 35 (3), 252-267.

Johnson, A., 1996, Rehabilitation and Re-use of Existing Buildings. In E. D. Mills ed. *Building Maintenance and Preservation: A Guide to Design and Management (2nd ed.),* UK: Oxford Architectural Press, 209-230.

Johnstone, I.M., 1995, An Actuarial Model of Rehabilitation Versus New Construction of Housing. *Journal of Property Finance,* 6(3), 7-26.

Kincaid, D., 2000, Adaptability Potentials for Buildings and Infrastructure in Sustainable Cities. *Facilities*, 18(3-4), 155-161.

Kincaid, D., 2002, *Adapting Buildings for Changing Uses: Guidelines for Change of Use Refurbishment.* London: Spon Press.

Kohler, N. and Yang, W., 2007, Long-Term Management of Building Stocks. *Building Research and Information*, 35(4), 351-362.

Koren, H.S. and Butler, C.D., 2006, The Interconnection Between the Built Environment Ecology and Health, *Environmental Security and Environmental Management: The role of Risk Management.* (5), 111-125.

Langston, C., 2008, The Sustainability Implications of Building Adaptive Reuse (keynote paper), *CRIOCM 2008, Beijing Oct/Nov*. 1-10.

Langston, C. and Shen, L.Y., 2007, Application of the Adaptive Reuse Potential Model in Hong Kong: A Case Study of Lui Seng Chun. *International Journal of Strategic Property Management,* 11(4), 193-207.

Larssen, A.K. and Bjorbery, S., 2004, Users' Demand for Functionality and Adaptability of Buildings – A Model and a Tool for Evaluation of Buildings, Proceedings of the *CIBW70 2004 Hong Kong International Symposium*, Kowloon Shangri-La Hotel, Hong Kong, 7-8 December, 167-176.

Latham, D., 2000, *Creative Re-use of Buildings– Principles and Practice*. Dorset,UK: Donhead Publishing Ltd.

Manewa, A., Madanayake, U., Ross, A., Siriwardena, M., 2016, Adaptable Buildings for Sustainable Built Environment. *Built Environment Project and Asset Management*, 6(2), 139-158.

O'Donnell, C., 2004, Getting serious about green dollars. *Property Australia*, 18(4), 1-2.

Petersdorff, C., Boermans, T., Stobbe, O., Joosen, S., Graus, W., Mikkers, E. and Harnisch, J., 2004, Mitigation of CO_2 Emissions from the EU-15 Building Stock: Beyond the EU directive on the Energy Performance of Buildings, *Environment Science and Pollution Research,* 13(5), 350-358.

Rawlinson, S. and Harrison, I., 2009, Cost Model Office Refurbishment, *Building Magazine*, 10(3), 48-53.

Remoy, H.T. and Van der Voordt, T. J. M., 2007, A New Life: Conversion of Vacant Office Buildings into Housing. *Facilities,* 2(3,4), 88-103.

Remoy, H.T. and Wilkinson, S.J., 2012, Office Building Conversion and Sustainable Adaptation: A Comparative Study. *Property Management,* 30(3), 218-231.

Reyers, J., and Mansfield, J., 2001, The assessment of risk in conservation refurbishment projects. *Structural Survey,* 19(5), 238–244. doi:10.1108/02630800110412480

Sheffer, D. A. and Levitt, R. E., 2010, How Industry Structure Retards Diffusion of Innovations in Construction: Challenges and Opportunities. Working Paper No. 59, *Collaboratory for Research on Global Projects*, Stanford University, Stanford, CA. Retrieved from: https://gpc.stanford.edu.

Shipley, R., Utz, S. and Parsons, M., 2006, Does Adaptive Reuse Pay? A Study of the Business of Building Renovation in Ontario, Canada. *International Journal of Heritage Studies* 12(6), 505-520.

Smith, J., 2005, Cost Budgeting the Conservation Management Plan. *Structural Survey,* 23(2), 101-110.

Snyder, G.H., 2005, Sustainability Through Adaptive Reuse. *The Conversion of Industrial Buildings. Master of Architecture, 101*. College of Design, Architecture, Art and Planning, Cincinnati, OH: University of Cincinnati.

Swallow, P., 1997, Managing unoccupied buildings and sites. *Structural Survey,* 15(2), 74-79. doi:10.1108/02630809710175137

Treloar, G., Love, P.E.D., Faniran, O.O. and Iyer-Raniga, U., 2000, A Hybrid Life Cycle Assessment Method for Construction. *Construction Management and Economics*, 18(1), 5-9.

Treloar, G., Love, P.E.D. and Holt, G.D., 2001, Using National Input-Output Data for Embodied Energy Analysis of Individual Residential Buildings. *Construction Management and Economics,* 19(1), 49-61.

Yung, E.H.K. and Chan, E.W.H., 2012, Implementation challenges to the adaptive reuse of heritage buildings: towards the goals of sustainable, low carbon cities. *Habitat International,* 36(3), 352-361.

Wilkinson, S. J., James, K. and Reed, R., 2009, Using Building Adaptation to Deliver Sustainability in Australia. *Structural Survey,* 27(1), 46 -61

Wilkinson, S. J., 2014, How Buildings Learn: Adaptation of Low Grade Commercial Buildings for Sustainability in Melbourne, Facilities, 32(7/8), 382-395.

Willis, J. (2007). *Foundations of qualitative research: Interpretive and critical approaches*. Thousand Oaks, CA: Sage.

Wood, B. and Muncaster, M., 2012, Adapting from Glorious Past to Uncertain Future. *Structural Survey,* 30(3), 219-231.

ESTIMATING WHOLE LIFE CYCLE CARBON EMISSIONS OF BUILDINGS: A LITERATURE REVIEW

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ABSTRACT

Building sector has been increasingly recognised as one of the significant sectors which emits considerable amount of carbon to the atmosphere. Therefore, lowering carbon emissions of buildings has become an essential response to the global carbon reduction targets. In response to that, many efforts have been put forward in estimating and reducing carbon emissions in this sector over the last few decades.

Whole life cycle carbon of a building is considered as the total amount of operational and embodied carbon occurred throughout its lifecycle. A building life cycle consists of four main phases as product, construction, operation and end of life. Even though, many studies have examined the whole life cycle carbon emissions during the assessment zones of operational and detailed design, it was found no studies have been conducted to examine the whole life cycle carbon emissions during early stage of a design. However, it is believed that the carbon emission reduction potential is high in the early stages of a project. Accordingly, the aim of this paper was to review the existing literature on building life cycle carbon estimation in order to identify the reasons for the less focus on early stage life cycle carbon estimation and to learn further research aspects on life cycle carbon estimation. A comprehensive literature review was carried out referring secondary data sources to achieve this aim. It was found out that insufficient primary data and limited approaches in estimating life cycle carbon as a major reason for the less focus on life cycle carbon estimations in early stage of design. Accordingly, it creates the need of a rigorous approach for early stage life cycle carbon estimating.

Keywords:*Buildings; Building Life Cycle****;*** *Carbon Emission; Life Cycle Carbon Estimation.*

1. INTRODUCTION

Since the onset of industrial revolution in late 18^{th} and early 19^{th} centuries, humans have been substantially influencing on climate system and the earth's temperature by burning fossil fuel, cutting down forests and increasing livestock farming etc. (Chandrappa *et.al,* 2011). As a result, this has now caused to rise the amount of carbon dioxide and other heat trapping gases such as methane and nitrous oxide which naturally present in the atmosphere, increasing the greenhouse effect and global warming (Halsnaes *et al.*, 2007 and US EPA, 2015). Report on climate change published by the Intergovernmental Panel on Climate Change (IPCC) (2014), clearly states that continued emissions of carbon will lead to a drastic change in climate and increase in temperature by 1.5^0C - 2^0C by the end of 21^{st} century. Therefore, it has become a top most priority in the world to reduce carbon emissions (Chau *et al*., 2015).

Accordingly, many strategies have been executed around the world with the aim of reducing global warming. Kyoto protocol is one such efforts made by United Nations in year 1998. It has introduced mandatory targets on reducing greenhouse-gas emissions for the world's leading economies who have accumulated historical emissions in the atmosphere since the beginning of the industrial revolution. The accepted targets for the first

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commitment period of 2008-2012 have ranged from -5 % to +10 % of the countries' individual 1990 emissions levels. Then the second commitment period started from 2013-2020 and the targets range from -5% to 40% from their individual base year emission levels.

In order to achieve these targets, the Committee on Climate Change (2013) has identified the building sector as one of the significant sectors which has a substantial potential in saving carbon in the short term. Buildings are responsible for more than 40% of global energy usage and as much as 33% of global greenhouse gas emissions in both developed and developing countries (Peng, 2015). Further, it has been estimated that the carbon emission of buildings across the world will reach 42.4 billion tonnes in 2035, which was 29.5 billion tonnes in 2007 (USEIA, 2010).

Therefore, considerable efforts across academia and industry have gone into estimating the carbon emissions of buildings, so as to reduce the carbon emission of buildings. Even though, many studies have examined the whole life cycle carbon emissions during the assessment zones of operational and detailed design, it was found no studies have been conducted to examine the whole life cycle carbon emissions during early stage of a design in which the high carbon reduction potential is expected. Accordingly, this paper reviews the existing literature on building carbon estimations to identify the major reasons for the less focus on whole life cycle carbon estimation during early stage of designs of a project and to learn further research aspects of this area.

2. RESEARCH METHOD

A comprehensive literature review was carried out to achieve the aim of the research. The method of desk study was adapted to collect data. Accordingly, secondary data related to building life cycle carbon emissions and estimation were gathered referring to related books, journal articles, government publications, web sites, newspaper articles, and other published reports. As this is a rapidly developing research area, the search results were limited to past 10 years.

3. LIFE CYCLE CARBON OF BUILDINGS

3.1. INTERPRETATION OF BUILDING LIFE CYCLE

Building is an extremely complex industrial product with a lifetime of decades (Airaksinen and Matilainen, 2011). There are few interpretations available for building life cycle in the existing literature. As illustrated in BS EN 15978:2011 (European Committee for Standardisation, 2011) (Refer Figure 1), building life cycle consists of 4 major stages namely;

1. Product stage
2. Construction process stage
3. Use (Operation) stage
4. End of life stage

There is one more stage beyond the life cycle called ‘Beyond the System Boundary’ which includes reuse, recovery and recycle. Similarly, Athena Sustainable Materials Institute (2014) has provided an interpretation for building life cycle and it includes six stages such as resource extraction, manufacturing, on-site construction, occupancy and maintenance, demolition and recycle, reuse and disposal. Contrary to BS EN 15978:2011, it has included reusing, recovery and recycling stage within the building life cycle.

However, the interpretation given by the BS EN 15978:2011 is widely accepted. According to that, product stage consists of the functions of extracting raw materials, refining (i.e. primary manufacture), transporting and processing them to produce a finished raw material (i.e. secondary manufacture). Construction process stage includes the functions of transportation of raw material in to the building construction site as well as enabling works, remediation, clearance, removal or demolition of existing structures, ground improvements, earthworks, assembly and completing the construction of the building. Use stage covers the functions of operating the building for the indented purpose, maintenance, repair, replacements and refurbishments of building. End of life stage consists of the functions of deconstruction or demolishing the building, waste processing, disposal and related transportation.

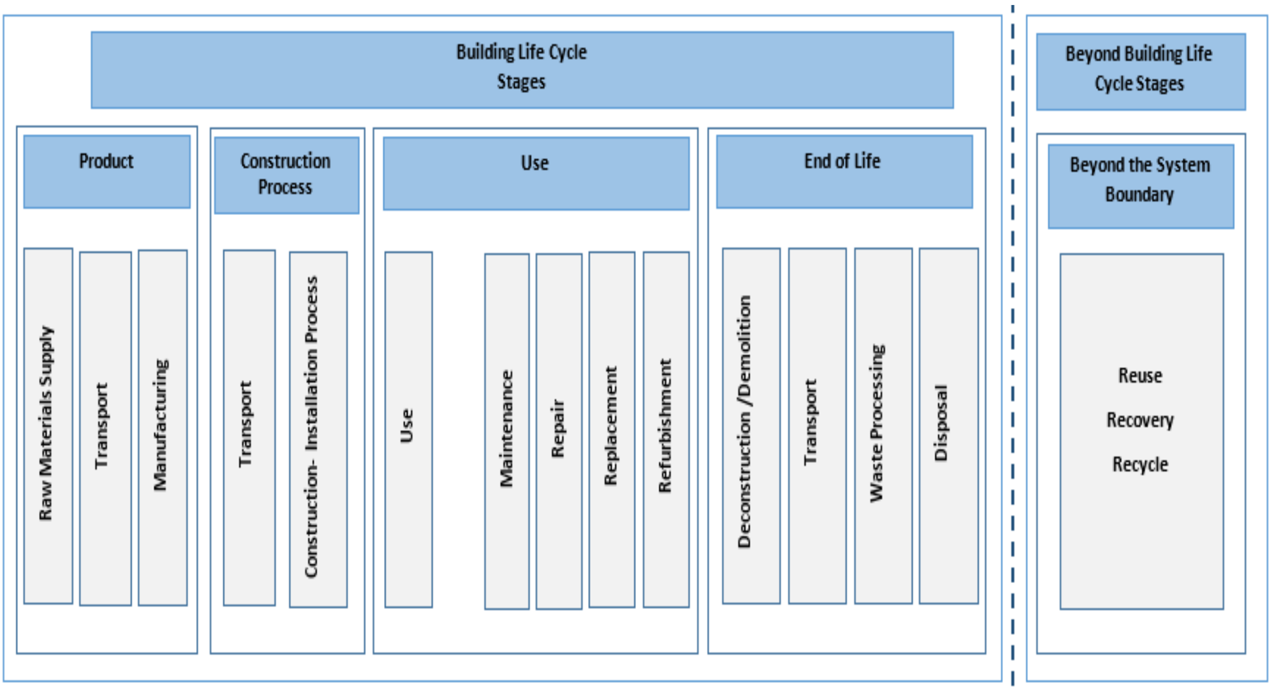

Figure 1: Building Life Cycle
(Source: European Committee for Standardisation, 2011)

3.2. *Types and Sources of Life Cycle Carbon*

A building, within its life cycle emits two types of emissions namely; operational carbon (OC) and embodied carbon (EC), depending on when carbon emissions occur in the life cycle (RICS, 2012). According to RICS (2012), operational carbon is the emissions occurring during the operational phase of a building and is typically generated from the operational energy consumption. This includes regulated load (heating, cooling, ventilation, lighting) and unregulated/plug load (ICT equipment, cooking and refrigeration appliances). Embodied carbon is the carbon emitting during the extraction, manufacture, transportation, assembly, replacement and deconstruction of construction materials or products of a building and are generally associated with energy consumption (embodied energy) and chemical processes (RICS, 2012). This has been clearly configured by UKGBC (2013) as in Figure 2.

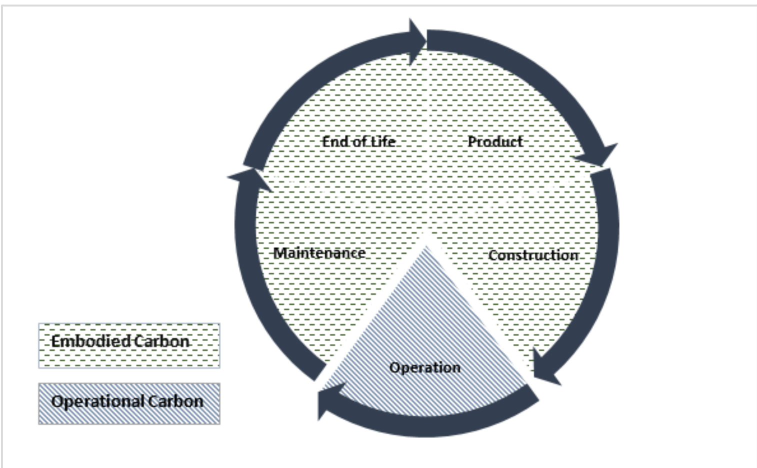

Figure 2: Carbon Emissions during Building Life Cycle
(Source: UKGBC, 2013)

Moreover, IPCC Guidelines for National Greenhouse Gas Inventories (2006) has identified that both of these emissions are generated from four main sources namely; industrial process (IE), energy consumption (EE), combustion of biodegradable organic matters (FE) and land use (LE) and You *et al*. (2008) has clearly categorised them into phases of building life cycle as in Figure 3.

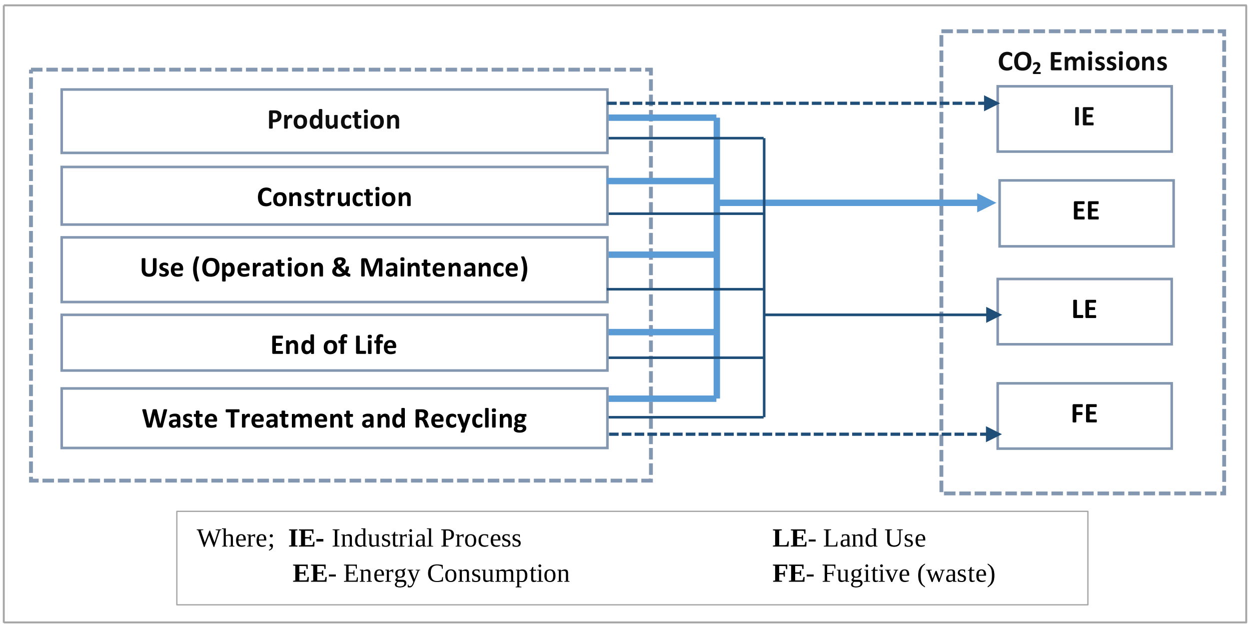

Figure 3: Coupling between Carbon Emissions and Building Life Cycle
(Source: You *et.al.*, 2011)

According to Figure 3, carbon (embodied) during product stage is emitted from IE, EE and LE. Construction stage emits carbon (embodied) from the sources of IE and LE. Operation stage emits operational carbon only from EE whereas maintenance stage emits embodied carbon from EE and LE. Carbon (embodied) emissions during the end of life and the waste treatment stages are from the sources of EE, LE and FE.

3.3. PROPORTION OF CARBON TYPES ACROSS DIFFERENT BUILDING TYPES

Many recent studies have detailed the proportion of life cycle embodied and operational emissions across different buildings. They have shown varying proportions to total lifecycle emissions due to the type of building being assessed, the use of building, the type of building materials used, construction methods employed, life span of the building and geographic differences etc. (Ibn-Mohammed *et.al*, 2013).

A study conducted by RICS (2012) to the UK context reveals that buildings such as supermarkets, offices and semi-detached houses are associated with 70 - 80% of operational carbon of the total life cycle emissions. Sartori and Hestnes (2007) have reviewed 60 case studies from past literature across different countries and reported that the embodied emissions could account for 2 - 38% of the total life cycle emissions while a larger portion remains as operational carbon. Further, Ramesh *et al*. (2010) have carried out a critical review of the lifecycle emissions analysis for residential and office buildings from 73 case studies across 13 countries and concluded that operational emissions accounted for 70 - 80%. Lin (2013) has also mentioned that the carbon emission from the operation stage accounted for the 60 - 80% emissions of total life cycle building carbon emissions in China. Accordingly, it is proved that operational carbon emissions are much higher than embodied emissions in typical buildings.

Contrary to typical buildings, RICS (2012) mentioned that the low energy incentive facilities such as warehouses accounts for only 20% of operational carbon emissions. This is further confirmed by Sartori and Hestnes (2007) in their study, stating that the low carbon buildings accounts for 9 - 46% of embodied carbon where the operational carbon remains in a lesser value. Unless in typical and low carbon buildings, zero carbon buildings emit zero operational carbon in which the total carbon emits as embodied carbon (RICS, 2012). Refer Figure 4 for a demonstration for embodied and operational carbon proportion of a typical, low carbon and zero carbon building.

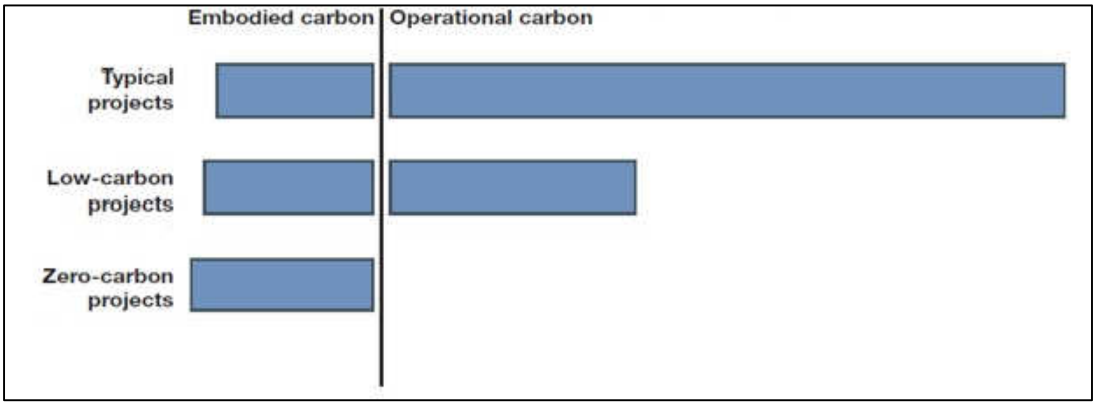

Figure 4: Life Cycle OC and EC Proportions of Buildings
(Source: RICS, 2012)

4. ESTIMATING WHOLE LIFE CYCLE CARBON OF BUILDINGS

4.1. *WHOLE LIFE CYCLE CARBON*

As mentioned by Ashworth and Perera (2015), the whole life cycle carbon of a building can be interpreted as shown in Eq. 01:

$$Whole\ Life\ Cycle\ Carbon = Life\ Cycle\ \ Operational\ Carbon\ +\ Life\ Cycle\ Embodied\ \ Carbon \quad \text{(Eq. 01)}$$

In a building, life cycle OC are only associated with the energy consumed during the operational phase. Therefore, measuring the life cycle operational carbon emission is relatively straightforward. Energy consumed in buildings is metered, with electricity, gas, petroleum and other energy sources metered through the energy supplier, so the estimations can be easily calculated (Ashworth and Perera, 2015).

Unlike that, life cycle EC emissions are occurred in all four phases of a building. Therefore, in estimating the EC of a building, measurement boundaries have been defined. As illustrated in Figure 5, there are five system boundaries namely; cradle (earth) to gate (manufacturing factory gate), cradle to site (construction site), cradle to end of construction, cradle to grave (demolition), or even cradle (earth) to cradle (reuse, recycle and recovery) (RICS,2012). According to that, life cycle EC requires to consider cradle (earth) to grave (demolition) system boundary, in which the embodied carbon emitted from materials extraction through manufacturing, transport, construction and use (building maintenance activities) to demolition of a building (whole life cycle) is considered. Thus, it is clear that the 'whole life cycle carbon emissions' is another term for 'cradle to grave emissions'.

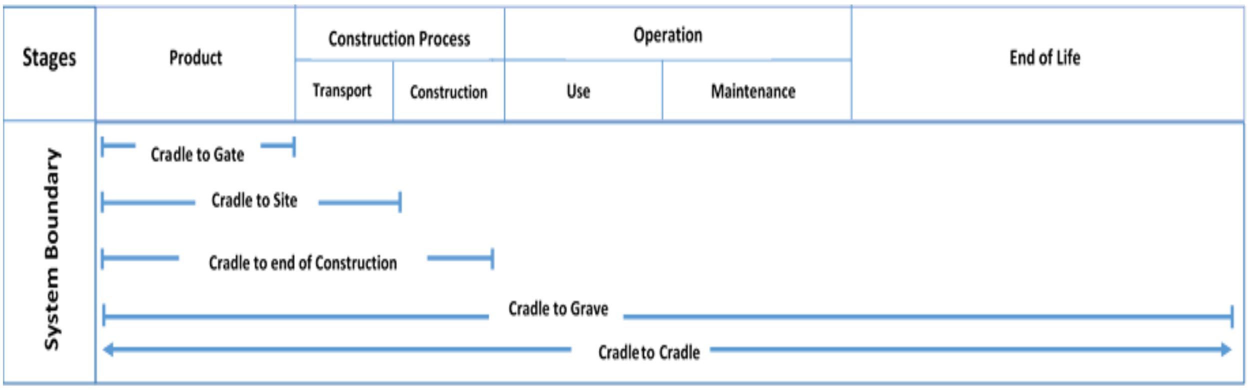

Figure 5: System Boundaries of Emission Calculation
(Source: RICS, 2012)

Further, when estimating life cycle carbon (either whole life cycle or any one type of carbon), RICS (2012) identifies five assessment zones of a construction project, where the carbon emissions assessment can be examined from. They are;

i. early stage estimating (concept design stages),
ii. design development stage estimating (developed design stage),
iii. detailed estimating (technical and specialist design stages),
iv. construction stage estimating (off-site and on-site construction),
v. building use stage estimating (use and aftercare).

Accordingly, the below stated carbon estimation tools and previous studies have been established as per one of these zones.

4.2. CARBON ESTIMATION TOOLS

There are many tools that have been developed to estimate the carbon emissions of buildings. Refer Table 1 for few of such efforts. While some of the tools listed in Table 1 assist in estimating whole life carbon, some tools assist only in estimating one type of carbon.

Table 1: Carbon Estimation Tools

Software and Tools	System Boundary	Type of Carbon	Assessment zone	Provider	Countries
Simplified Building Energy Model	Operational Stage	OC	operational stage	Building Research Establishment (BRE)	UK
LSA in sustainable Architecture	Cradle to Grave	OC+EC	operational stage	BHP Laboratory	Australia
Athena Impact Estimator version 5.2	Cradle to Grave	EC	design stage	Athena Sustainable Materials Institute	USA, Canada
ENVEST2	Cradle to Grave	EC	early stage	Building Research Establishment (BRE)	UK
Global Environmental Model/Management-21P (GEM- 21P)	Cradle to Grave	OC+EC	design stage	Shimizu Construction	Japan
Simple Carbon Calculator	operational	OC	operational stage	National Energy Foundation	UK
Green House Gas Calculator	operational	OC	operational stage	Environmental Protection Authority	Australia
The Build Carbon Neutral Construction Calculator	Cradle to Grave	EC	early stage	Build Carbon Neutral Organisation	USA

Carbon tools such as Simplified Building Energy Model (Building Research Establishment, 2010), Simple Carbon Calculator (National Energy Foundation, 2015) and Greenhouse Gas Calculator (Environmental Protection Authority) have only focused on life cycle operational carbon emissions and limited to the assessment zone of operational stage. Tools such as Athena Impact Estimator version 5.2 (Athena sustainable Materials Institute, 2017), ENVEST2 (BRE and The Build Carbon Neutral Construction Calculator (Build Carbon Neutral Organisation, 2007) have focused life cycle embodied carbon and limited to design and early stage. It was found only very few tools which have been developed to estimate whole life cycle carbon emissions. LCA in sustainable Architecture (BHP Laboratory, 2011) and Global Environmental Model/ Management-21P (GEM- 21P), (Shimizu Construction, n.d) are two examples for whole life carbon estimators. Although there are many carbon estimation tools, the above Table indicates that they have different limitations inherent to themselves.

4.3. PREVIOUS STUDIES ON WHOLE LIFE CYCLE CARBON ESTIMATION

Table 2 presents few studies that have been conducted in different countries focusing various buildings to assess the whole life cycle carbon emissions. It shows that most of the assessments have been carried out during operational stage of that particular project.

Table 2: Previous Studies on Building Life Cycle Carbon Assessment

Country	Author	Assessment Zone	Type of Building
UK	Darby et.al (2011)	Operational Stage	Warehouse Building (Book Storage Facility)
	Hacker (2008)	Operational Stage	Semi- detached Two Bed Room House
China	You et.al (2011)	Operational Stage	Urban Residential Buildings
	Hu and Zheng (2015)	Operational Stage	Energy Efficient Residential Buildings
Finland	Airaksinen and Matilainen (2011)	Design Stage	Office Building
South Korea	Cho and Chae (2016)	Operational Stage	Office + Residential

5. DISCUSSION

This study set out with the aim of reviewing existing literature on whole life cycle carbon emission assessment of buildings. Building sector being one of the major culprits for the high carbon emissions, now the significant attention is being paid on whole life cycle carbon assessments with the intention of meeting global carbon reduction targets. The literature review demonstrated that the whole life cycle carbon emission consists of life cycle OC and life cycle EC. While estimation of life cycle OC associated with operational phase of a building, estimation of life cycle EC associates with all four phases of a building, creating the measurement boundary of cradle to grave.

Even though there are few whole life cycle carbon estimating tools as shown in Table 1, each tool is different and do have limitations. Major limitation is to be the applicability of the tools which depends on the context and type of the building. Further, Peng (2015) mentioned that the calculation tools used in developed regions cannot be applied mechanically in developing areas as carbon emissions from a building’s life cycle have distinct regional characteristics because of the different types of climates, management policies, and technological levels in different places. As mentioned by De Wolf *et al.* (2017) another limitation is their less transparency and not keeping up to date. Further, as it is mentioned above, another common limitation among these tools is the system boundary and assessment zone. Therefore, the simulation of carbon emissions from a building’s life cycle has become more complicated and the results of calculation appeared more different (Victoria *et al*, 2015 and Peng, 2015).

Table 2 presents few studies that have been conducted over the last ten years period focusing whole life cycle carbon emissions. It indicates that some of the studies have been conducted in the assessment zone of operational carbon and some in design zone, but no case study found that have been conducted during early design stage. Ashworth and Perera, (2015) mention that limited amount of design information available at early design stage as the main reason for this gap. Further, RICS (2012) mentions that early in the design process, high levels of uncertainty can be seen in the design details, making the calculation process more complex. Therefore, studies and the estimation tools focused on whole life carbon calculation during early design stage are not well established yet. However, RICS (2012), further recommends that if it starts to assess carbon emissions in early stage of a project, then its ability in reducing whole life carbon emission is high. Therefore, it creates a necessity of having a better approach in estimating whole life carbon in early design stage of a construction project.

6. CONCLUSIONS AND THE WAY FORWARD

The aim of this paper was to carry out an extensive literature review on whole life cycle carbon estimation of buildings. Accordingly, the existing literature on building life cycle, types of life cycle carbon, life cycle carbon estimation tools and previous case studies on whole life cycle carbon estimation were reviewed.

Even though high carbon emission reduction potential is expected during early stage of a project, the findings indicated that most of the carbon estimation tools and the previous studies have focused estimation during operational stage and design stage. It was found out that lack of early stage estimation procedures and required data sets as the main reason for that gap. However, addressing this gap will eliminate unnecessary carbon emissions rather managing them in later stages. Hence, there is a necessity to fill that gap by introducing a rigorous approach to predict the whole life cycle carbon emission at early stage of designs in order to facilitate designers, engineers, users, and decision-makers with accurate evaluation of carbon emissions.

7. REFERENCES

Airaksinen, M. and Matilainen, P., 2011. A Carbon Footprint of an Office Building, *Energies*, 4, 1197-1210.

Ashworth, A., and Perera, S., 2015. *Cost of studies of buildings*. 6th ed. Oxon: Routledge.

Athena Sustainable Materials Institute, 2014. *User Manual and Transparency Document, Impact Estimator for Buildings*, Canada: Athena Sustainable Materials Institute.

Athena Sustainable Materials Institute, 2017 *Athena Impact Estimator version 5.2.* [online]. Available from: https://calculatelca.com/software/impact-estimator/ [Accessed 01 June 2017]

BHP Laboratory, 2011. *LSA in sustainable Architecture.* [online]. Available from: www.lisa.ac.com. [Accessed 01 June 2017]

Build Carbon Neutral Organisation, 2007. *The build carbon neutral construction calculator.* [online]. Available from: http://buildcarbonneutral.org/. [Accessed 01 June 2017]

Building Research Establishment (BRE), 2010. *SBEM: Simplified building energy model*. [online]. Available from: https://www.bre.co.uk/page.jsp?id=706. [Accessed 01 June 2017]

Building Research Establishment (BRE), (n.d.), *ENVEST2.* [online]. Available from: http://envest2.bre.co.uk/. [Accessed 01st June 2017]

Chandrappa, R., Gupta, S. and Kulshrestha U.C., 2011. *Coping with climate change: Principles and Asian context.* Berlin: Springer.

Chau, C.K., Leung, T.M. and Ng, W.Y., 2015. A review on life cycle assessment, life cycle energy assessment and life cycle carbon emissions assessment on buildings. *Applied Energy*, 143, 395- 413.

Cho, S.H., and Chae, C.U., 2016. A Study on Life Cycle CO2 Emissions of Low-Carbon Building in South Korea, *Sustainability*, 8(579), 1-19.

Committee on Climate Change, 2013. *Fourth carbon budget review – part 2 the cost-effective path to the 2050 target.* UK: Committee on Climate Change.

Darby, H.J. Elmualim, A.A. and Kelly, F., 2011. Case study on the whole life carbon cycle in buildings, *World Renewable Energy Congress 2011*. Sweden 8 - 13 May 2011, Sweden: Linkoping.

De Wolf, C., Pomponi, F., and Moncaster, A., 2017. Measuring embodied carbon dioxide equivalent of buildings: A review and critique of current industry practice, *Energy and Buildings*, 140, 68–80.

Environmental Protection Authority (EPA), (n.d.) *Greenhouse gas calculator.* [online]. Available from: http://www.epa.vic.gov.au/agc/home.html. [Accessed 01 June 2017]

European Committee for Standardisation, (2011). *European Committee for Standardisation*. BS EN 15978:2011

Hacker, J.N., De Saulles, T.P., Minson, A.J. and Holmes M.J., 2008. Embodied and operational carbon dioxide emissions from housing: A case study on the effects of thermal mass and climate change, *Energy and Buildings*, 40, 375–384.

Halsnaes, K., Shukla, P., Ahuja, D., Akumu, G, Beale, R., Edmonds, J., Gollier, C., Greubler, A., Ha Duong, M., Markandya, A., McFarland, M., Nikitina, E., Sugiyama, T., Villavicencio, A and Zou, J. 2007. Framing issues. In: Metz, B., Davidson, O.R., Bosch, P.R., Dave, R. and Meyer, L.A., eds. *In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, New York. Cambridge: Cambridge University Press.

Hu, F. and Zheng, X., 2015. Carbon Emission of Energy Efficient Residential Building, *Procedia Engineering*. 121, 1096 –1102.

Ibn-Mohammed T., Greenougha, R., Taylorb, S., Ozawa-Meidaa, L. and Acquayec, A., 2013. Operational vs. embodied emissions in buildings—A review of current trends, *Energy and Buildings*. 66, 232–245.

Ibn-Mohammed, T., 2014. *Optimal ranking and sequencing of non-domestic building energy retrofit options for greenhouse gas emissions reduction*. Thesis (PhD). De Montfort University, Leicester.

Intergovernmental panel on climate change (IPCC), 2014. *Climate change 2014; Impacts, adaptability and vulnerability*. IPCC WGII AR5.

IPCC Guidelines for National Greenhouse Gas Inventories, 2006. [online]. Available from: http://www.ipcc-nggip.iges.or.jp/public/2006gl/ [Accessed 26 February 2017].

ISO, 2006. *ISO 14040:2006: Environmental management -Life cycle assessment - Principles and framework*

Kyoto Protocol to The United Nations Framework Convention on Climate Change 1998. [online]. Available from: https://unfccc.int/resource/docs/convkp/kpeng.pdf [Accessed 12th March 2017]

National Energy Foundation, 2015. *Simple carbon calculator*. [online]. Available from: http://www.carbon-calculator.org.uk/ [Accessed 01 June 2017]

Peng C, 2015. Calculation of a building's life cycle carbon emissions based on Ecotect and building information modeling, (2016), *Journal of Cleaner Production*, 112, 453–465.

Ramesh, T., Prakash, R., and Shukla, K. K., 2010. Life cycle energy analysis of buildings: an overview, *Energy and Buildings*, 42 (10), 1592–1600.

RICS, 2010. *Research report on carbon profiling as a solution to whole life carbon emission measurement in buildings*, RICS.

RICS, 2012. *Methodology to calculate embodied carbon of materials, RICS professional guide global*, 1st ed. RICS.

Sartori, I. and Hestnes. A.G., 2007. Energy use in the life cycle of conventional and low-energy buildings: a review article, *Energy Building*, 39, 249–257.

Shimizu Construction, (n.d). *Global Environmental Model/Management-21P (GEM- 21P)*

UKGBC, 2013. *A methodology for measuring embodied carbon*. [online]. Available from: http://www.ukgbc.org/sites/default/files/How%20to%20measure%20embodied%20carbon%20session%202.pdf [Accessed 14 March2017]

US Environmental Protection Agency (US EPA), 2015. *Causes of climate change.* [online]. Available from: https://www.epa.gov/climate-change-science/causes-climate-change [Accessed 12 February 2017]

USEIA, 2010. *International Energy Outlook.* [online]. Available from: http://large.stanford.edu/courses/2010/ph240/riley2/docs/EIA-0484-2010.pdf. [Accessed 12 February 2017]

Victoria, M., Perera, S. and Davies, A., 2015. Developing an early design stage embodied carbon prediction model: A case study In: Raidén, A B and Aboagye-Nimo, E, ed. In *31st Annual ARCOM Conference*, 7-9 September 2015, Lincoln, UK: Association of Researchers in Construction Management, 267-276.

You, F., Hua, D., Zhang, H., Guo, Z., Zhao, Y., Wanga B. and Yuan, Y., 2011. Carbon emissions in the life cycle of urban building system in China - A case study of residential buildings, *Ecological Complexity*, 8, 201–212.

EVALUATING INNOVATIVE TECHNOLOGIES IN CONSTRUCTION INDUSTRY: THE CASE OF HIGH RISE BUILDINGS

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ABSTRACT

Construction industry is associated with risks and uncertainties, due to its nature. On the other hand, those risks and uncertainties have instigated the discovery of innovative technologies to eliminate risks and uncertainties. Although technologies in construction industry is being innovated to provide solutions for potential issues on time, cost, quality, and sustainability, past researches still emphasis that the construction industry is not yet developed as other parallel industries. In the post war period, Sri Lankan construction industry became vast and advance with high rise building constructions. Land scarcity and high population growth are reasons for such tremendous development of high-rise buildings. However, the deficiency in the development of technologies in the construction industry does not fulfil modern necessities.

Therefore, the purpose of this research paper is to investigate the innovative technologies adopted in high rise building construction projects in Sri Lanka, for a successful completion within the budget, on time, and with adequate quality. A comprehensive literature review survey was performed to identify innovative technologies integrated in building construction industry during the design and construction development phases. Data were collected through eight (08) ongoing high rise building projects located in urban Colombo area, and these data were categorized according to the cases and presented as percentages among the projects. The results from the study revealed that the use of innovative technologies vary, and currently, common technologies are used during the design and construction phases. Further, the study identified identical benefits the client and the contractor can gain by using innovative technologies, and the challenges faced by industry stakeholders.

Keywords: *Benefits; Challenges; High-rise buildings; Innovative technologies.*

1. INTRODUCTION

Construction is defined as the combination of physical infrastructure, civil-engineering work, all building work, and the maintenance and renovation of existing structures (Wells, 1985). However, because of its nature, the construction industry is associated with risks and uncertainties. According to Dubois and Gadde (2002), uncertainty in construction happens due to four major reasons: (1) management is unfamiliar with local resources and the local environment; (2) lack of complete specifications for construction activities; (3) lack of uniformity of projects; and (4) unpredictability of the environment. Nguyen and Chileshe (2015) stated that outdated technologies are a major reason for a project failure, while Assaf and Al-Hejji (2006) implied that lack of innovative technology implementation cause project to delay. This bears evidence that the construction industry require innovative technologies for managing risks and uncertainties. Consequently, Rosenberg (2004) said that “Uncertainty” is the single feature that dominates the search for innovative technologies and innovation must have been a major force in the growth of output in highly industrialized economies.

As per Kavilkar and Patil (2014), innovative technologies support the construction of safer and economical buildings. According to Warszawski and Navon (1998), the main aspects of innovative technologies are maximizing production, minimizing labour resource, and improving quality. Rosenberg (2004) argued that the mechanized manufacturing methods reduce labour cost up to 30%, and Bock (1998) stated that using

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innovative technologies can save time, cost, and quality of the product. In the same way, Kyjakova, *et al.* (2014) reported that innovative technologies permit the construction of attractive buildings of any size, preferably with several storeys, and custom designed to meet specific requirements. Egan (1998) and Benmansour and Hogg (2002) explored the benefits due to innovation in the construction as improved living and working conditions, lower costs, sustainability, high profitability, and a lesser impact on the consumption of energy and environment. While the Sri Lankan construction industry is in boom through the past decade, innovative technologies entered in to Sri Lankan industry more than ever in the post-conflict scenario in the country, after the end of the ethnic war in 2009. With the revolution of the construction industry, more of high rise building projects started than in the past, especially in Colombo and suburban areas. Therefore, the purpose of this paper is to investigate the innovative technologies adopted in high rise building construction projects in Sri Lanka. Various authors used different terminologies for innovative technologies such as modern technologies (Väha *et al*., 2013), advanced technologies (Kildienė, *et al.*, 2014) and new technologies (Hing, 2006), but the term 'innovative technology' was adopted throughout this research study.

The paper structure begins with an introduction to the study, followed by a literature review on necessity of innovative technologies in high rise building construction industry, drivers, benefits, and challenges. The research methodology, data collection, and data analysis are presented next, and finally, the paper presents conclusions derived from research findings with recommendations.

2. LITERATURE REVIEW

2.1. INNOVATIVE TECHNOLOGIES IN CONSTRUCTION INDUSTRY

The definition given for innovation by Slaughter (1998) is, "the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change." According to Ling (2003), innovation is "a new idea that is implemented in a construction project with the intention of deriving additional benefits, although there might have been associated risks and uncertainties." Moreover, it is pertinent to note current industrial practices deviating from the conventional path of innovative technologies. Puddicombe (1997) highlighted that in response to the increasing complexity of modern construction projects, industry practitioners have differentiated themselves. "Already there have been many efforts to apply the evolving computer science software technologies loosely called 'artificial intelligence' to construction" (Bock, 1998). Furthermore, Sakamota and Mitsuoka (1994) stated that new machines need to be developed for better usage and improvement of the productivity in building construction. Moreover, Sakamota and Mitsuoka (1994) explored the mechanized construction system, which is carried out by machines, by considering the introduction of technologies and ideas from construction to other sectors such as mechanical engineering, electrical engineering, electronic engineering, and Information Technology (IT) sections.

Hu (2016) argued that the people's demand for construction development is the pathway for the technological innovation of construction that can support the builders to achieve their goals. According to Hu (2016), innovative technologies can ensure the aspects of a construction project and builders can improve safety during construction. Furthermore, the same author mentioned that innovative technologies and techniques are strategies to save resources and implement environmental-friendly constructions. Then the development of projects and sustainable development of human society become major aspects of innovative technologies. The author further argued that saving time, shorter construction period, saving labour costs, and improved quality, are the general aspects of innovative technologies, whereas ultimate output of innovative technologies is improving the living conditions of people in the society. Kildienė *et al.* (2014) stated that construction innovation is more effective than conventional methods and some are novel solutions for problems confronted in conventional methods.

Kildiene *et al*. (2014) explained that the improvement of the quality of human behaviour, distribution of technologies, reducing cost and time, and sustainability, are the aims of the construction sector. A key feature to achieve such aims is the use of innovative construction materials and technologies. Figure 1 illustrates the concept of development of the advance technologies. According to Kildiene *et al*. (2014), innovative technologies in the construction industry fulfil the major concern on cost, time, and sustainability, which are developed and tested as a prototype model in the laboratory and environment to provide the optimum output (refer Figure 1).

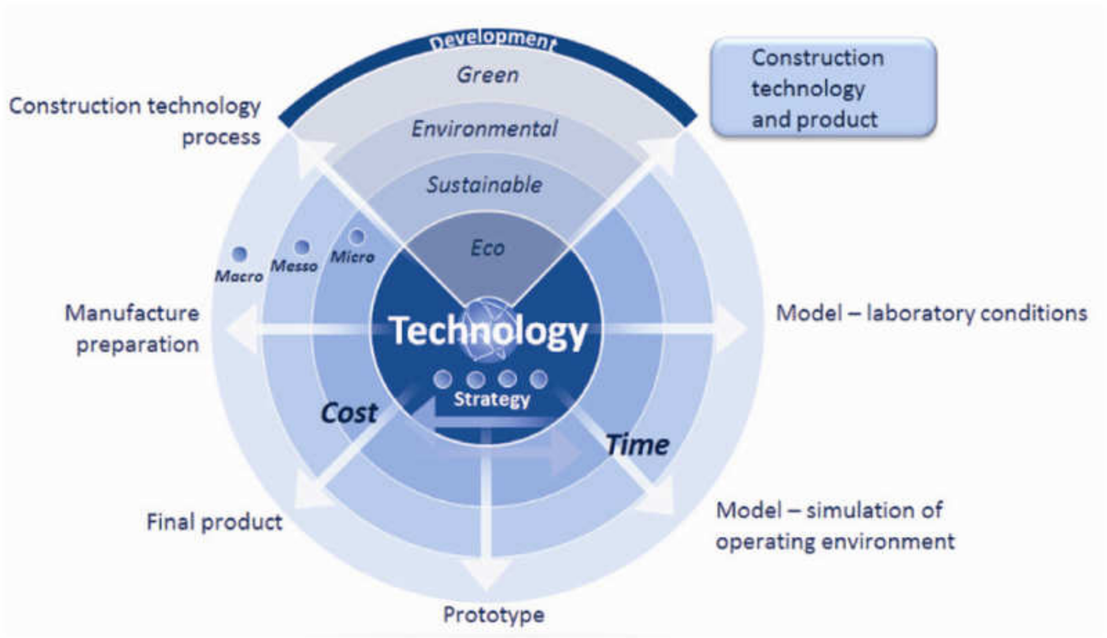

Figure 1: Advance Technology Development Concept

(Source: Kildienė *et al.*, 2014)

2.2. INNOVATIVE TECHNOLOGIES IN HIGH RISE BUILDING CONSTRUCTION

Thapa, *et al*. (2013) identified that massive population and land scarcity increase the demand for high rise buildings. The authors argued that innovative technologies are major factors for the success of high rise building construction. The technological development, population density, good financial power, and reputational competition, increase the demand for high rise building construction. Many authors have discussed innovative technologies which can adopt during the design phase, substructure construction phase, and superstructure construction phase. Dossick and Simonen (2014) introduced BIM as a solution to a potential problem in high rise building design due to scope, complexity, and constructability, and explained that potential conflicts can be solved by BIM before the construction. Alshanbar (2014) stated that BIM is an innovation tool in the design process in modern construction.

Sandelin and Budajev (2013) identified wind as a major problem in high rise building construction and explained various tubular systems in the current construction industry. Vähä, Heikkilä, and Kilpeläin (2013) identified automated operation in digital form for measuring work, levelling, and surveying, as an alternative for manual measurement tools tape measures, transits, levels, and plummets. Digital theodolites or tachometer (a combination of a theodolite and an electronic distance measuring device), GNSS (Global Navigation Satellite System), laser planes levels, and plummets, are used for positioning purposes.

Haowen (2015) specified that innovative formwork systems are the best solution for difficulties faced in high rise buildings, such as high position for work, low position for supporting, aerial movement of formwork, and sufficient strength. PERI formwork system (Loret *et al*., 2015), crane operated climbing formwork system (Dahlin and Yngvesson, 2014), andslipping formwork system (Loret *et al*., 2015), are some advance formarwork systems discussed in the literature. Iwiss (2008) introduced electric rebar cutter machines that can cut rebar easily and accurately. When the diameter of the reinforced bar increase, the lap length also increase. As a solution, Outakumpu (2013) introduced reinforced bar couplers that are more cost effective and save 52d length in each bar. Väha *et al.* (2013) described about an innovative machine for plastering and explained on uniqueness. Table 1 presents some innovative technologies used in high rise building construction during design phase, substructure construction phase, and superstructure construction phase, identified through a critical literature review.

Table 1: Innovative Technologies in High Rise Building Construction during Design and Construction Phases

Building Phase	Innovative technologies	
Design Phase	**Building Information Modelling(BIM)** (McCuen and Tamera, 2014; Alshanbar, 2014)	
	Frame (Design developments in structure) (Sandlin and Budajev, 2013)	**Tubular systems** (Sandlin and Budajev, 2013)
	Dampers	Trussed tube system
	Shear wall	Bundled tube system
	Rigid frame	Tube in tube system
	Bracing	Core with outrigger system
	Braced rigid frame	Buttressed core system
		Tubed mega frame system
Construction Phase- Sub Structure	**Earthmoving works (intergraded with any other method) (***Pan and Hou, 2016)*	
	Measuring Tools (Digital or any)	**Pile Foundation (Väha *et al.*,2013)**
	Levelling Tools (Digital or any)	*Automated piling systems*
	Surveying Tools (GPS or any)	*PHC screw piles*
	Positioning Tools (GPS or any)	*Large diameter bored pile*
		H-pile
		Mini-pile foundation
		Intergraded with GPS
Construction phase-Super structure	**Formwork material**	***In situ* concrete**
	Aluminium formwork	*Self-compacting concrete*
	Fibber glass formwork (Richard,1962)	*Self-levelling and self- curing concrete*
	Plastic formwork	*Magnetically driven concrete*
	Advanced formwork systems	*Self-healing concrete* (Honkers, 2011)
	Crane-operated climbing formwork	*Alternative for Portland cement*
	*System formwork (PERI System) (*Loret *et al*., 2015)	**Light weight concrete**
	Slip formwork system (Loret *et al*., 2015)	**Carbon nanotubes**
	Hoisting and Working platform (Acuna, 2000)	**Pumping system**
	Gondola/Swinging Stage	*Truck-mixture concrete pumps*
	Work platforms	*Staged pumping*
	Automated building construction system (ABCS) (Miyakawa*et al*., 2000)	*Stationary concrete pumps and booms*
	Automated crane	**Prefabrication of elements** (Acuna, 2000)
	Reinforcement (Thillairaja, *et al*., 2015;Iwiss, 2008; Outakumpu, 2013)	*Pre-tension concrete element*
	Reinforced bar bending machine	*Post-tension concrete element*
	Rebar cutter (RC)	*Precast concrete*
	Portable rebar tying tools	**Contour crafting (layer fabrication)**
	Reinforced bar coupler in columns	**Sandwich panel**
	Cup lock Scaffolding (SGB-Group,2005)	
Finishes (Väha *et al*., 2013)	**Plastering machinery**	**Tiling machines**
	Painting machines	**Epoxy flooring**
		Power trowelling

2.3. *DRIVERS AND BARRIERS TO IMPLEMENT INNOVATIVE TECHNOLOGIES*

Ahn *et al*. (2013) identified some drivers to implement innovative technologies with sustainable construction as follows: Energy, environmental, and resource conservation, Regulations and policies, Reduction of waste, Proactive of product and materials, Cost transparency, Building rating methods (LEED, Green Globes), Educating and training facilities, Recognition of commercial buildings as assets, Proactive performance, Success of complicated high rise building design, New kinds of procurement methods, High productivity, Improving sustainability and quality, Awareness from clients, Improving social benefits, and cost reduction. Winch (2003) stated the productivity, quality, and value of money, were not developed with parallel industries due to lack of innovation in construction.

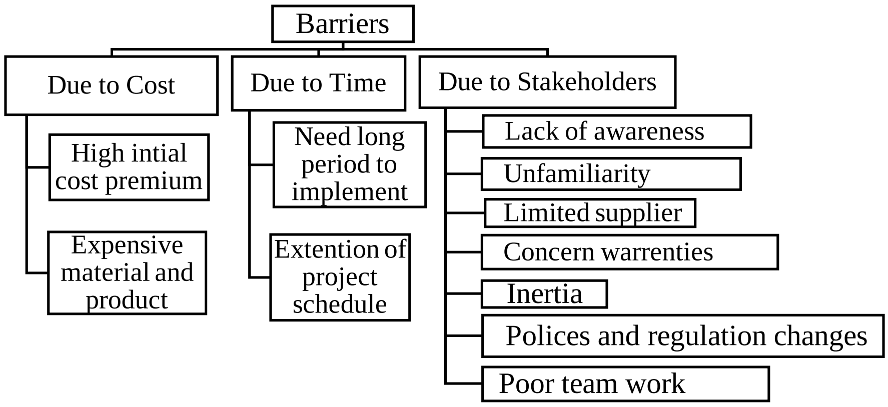

Figure 2: Barriers for Implementing Innovation Technologies

(Source: Ahn *et al*., 2013)

Benmansour and Hogg (2002) investigated barriers to adopt innovative technologies to a project due to deficiency of infrastructure, shortages in education and training, legislation problems, discouraged aspects of clients and engineers, and production of unique. Ahn *et al*. (2013) identified that barriers for innovation technologies depend on sustainable construction. Those barriers could divide into main three groups; barriers due to cost, barriers due to time, and barriers due to stakeholders. Figure 2 illustrates such barriers under each heading.

3. RESEARCH METHODOLOGY

This research paper aims to investigate the innovative technologies adopted in high rise building construction projects in Sri Lanka for a successful completion within the budget, on time, and with adequate quality. To fulfil the research aim, the study selected eight (08) ongoing high-rise buildings, with over twenty storeys (20) and located in Colombo area, to investigate the current innovative technologies adopted during design and construction phases. As stated by Denzin and Lincin (2005), qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them. Case analysis data were summarised using the frequency and percentage basis. Table 2 illustrates general information of the selected cases.

Table 2: Profile of the Case Analysis

Description	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
Type	Hotel Building	Office Building	Residential Building	Multi purposive commercial building	Multi purposive commercial building	Office building	Residential Building	Residential Building
Employer	Private	Government	Private	Private	Private	Government	Private	Government
Contractor	Local	JV	Foreign	JV	Foreign	JV	JV	Local
Condition	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing

ICTAD grading	C1 contractor	C1 contractor	C1 contractor	C1 contractor	C1 contractor	C1 contractor	C1 contractor	C1 contractor
Contract price	Rs. 9.0 Billion	Rs. 8.0 Billion	Rs. 14.7 Billion	Rs. 92.5 Billion	Rs. 31 Billion	Rs. 7.4 Billion	Rs. 7.0 Billion	Rs. 5.7 Billion
Height	205m	140m	264m	156m	175m	74m	77m	70m
No. of towers in Building	1	1	2	3	2	1	1	1

4. DATA ANALYSIS AND FINDINGS

The study findings discussed the use of innovative technologies under main four phases; Design phase, Substructure phase, Superstructure phase, and Finishes phase. In each case, the relevant information was collected through project managers, site engineers, project architects, project quantity surveyors, and technical officers where necessary.

4.1. ANALYSIS OF INNOVATIVE TECHNOLOGIES ADOPTED IN DESIGN PHASE

The current practice of innovative technologies during the design phase was summarized in Tables 3 and 4, based on the professional response.

Table 3: Analysis of Innovative Technologies in Design Phase

Innovative Technology	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	%
BIM	X	X	√	√	√	X	X	X	37.5
Dampers	X	X	X	X	X	X	X	X	0.0
Shear wall	√	√	√	√	√	√	√	√	100.0
Rigid frame	√	√	√	√	√	√	√	√	100.0
Bracing	X	√	X	X	√	X	√	X	37.5
Braced rigid frame	X	X	X	√	X	X	X	X	12.5

According to Table 3, some technologies are not yet practised while some have become common to all cases. Dampers have not been adopted in these projects and the braced rigid frame is less practised. On the other hand, shear wall and rigid frame are used in all projects. It revealed that these are the most popular techniques to withstand wind load, and became a common technology to all cases. Table 3 depicts the bracing is used in three projects, and BIM is executed in Cases 3, 4, and 5. The BIM applications were used in the above cases; however, these cases have not obtained the concept of BIM fully. “Revit” application was executed in most cases, and the emerged fact is, consultancy organizations, if they are foreign organizations, executed BIM. The findings revealed that Case 5 practiced higher innovative technologies compared to other projects. The lowest practicing was reported from Cases 1 and 8.

Table 4: Analysis of Tubular System

Innovative Technology (Tubular Systems)	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	%
Frame tube system	X	X	X	X	√	X	X	X	12.5
Trussed tube system	X	X	X	X	X	X	X	X	0.0
Bundled tube system	X	X	X	√	X	X	X	X	12.5
Tube in tube system	X	X	X	√	X	X	X	X	12.5
Core with outrigger system	√	X	√	√	X	√	X	√	62.5
Buttressed core system	X	X	X	X	X	X	X	X	0.0
Tubed mega frame system	X	X	X	√	X	X	X	X	12.5

The literature search identified seven tabular systems used in building projects. Based on Table 4, core with outrigger system was the most popular tubular system, since the core is a major concern in high rise buildings. The core was used to fix the lifts and used as services ducts. Hence, tube becomes a core part of the high-rise building constructions. However, trussed tube system and buttressed core system were not practised in any selected projects. Among them, Case 4 practised higher amount of innovative techniques under tubular system, where three proposed building towers could be seen under Case 4.

4.2. *Analysis of Innovative Technologies adopted in Substructure Phase*

Table 5 illustrates innovative technologies used in substructure phase with their percentages. In substructure phase, the measuring tool and large board piles received the highest percentage of 100%. The innovative total station is an electronic theodolite integrated with electronic distance meter (EDM). The respondents in Cases 1, 2, and 3 said that these are more accurate and highly user friendly. Therefore, they tend to use it as a measuring tool in high rise building constructions. Moreover, respondents highlighted that small errors in levelling, measuring, surveying, or positioning in bottom, will be a dominant issue due to height. All respondents indicated that accuracy in equipment is of high concern in high rise building construction. Therefore, electronic levelling tools and surveying tools become the trend. GPS integrated system is used for positioning, and laser plummet facilitates measuring and positioning due to high accuracy. As Table 5 depicts, those receive higher percentages comparatively. Almost all projects uses the large diameter board piles. Only Case 1 used piling machines integrated with GPS, but none of the projects used automated piling systems, PHC screw piles, and mini piles, because those are intended for special requirements. In addition, Cases 1, 3, and 8 used earthmoving machines integrated with GPS system, although the earthmoving machines can be only indicated in the marked positions.

Table 5: Innovative Technologies Adopted in Substructure Phase

Innovative Technology	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	%
Earthmoving works (GPS)	√	X	√	X	X	X	X	√	37.5
Measuring Tools (Digital or any)	√	√	√	√	√	√	√	√	100.0
Leveling Tools (Digital or any)	√	√	√	X	√	√	√	√	87.5
Surveying Tools (GPS or any)	√	√	√	X	√	√	√	√	87.5
Positioning Tools (GPS or any)	√	√	√	√	X	√	√	√	87.5
Pile Foundations									
Integrated with GPS	√	X	X	X	X	X	X	X	12.5
Automated piling system	X	X	X	X	X	X	X	X	0.0
PHC screw piles	X	X	X	X	X	X	X	X	0.0
Large diameter bored pile	√	√	√	√	√	√	√	√	100.0
H-Pile	√	√	X	X	X	√	√	X	50.0
Mini-pile foundation	X	X	X	X	X	X	X	X	0.0

Respondents of Cases 1, 2, 4, and 5, highlighted earth retaining technologies since deep excavations are involved in basement and pile caps in high rise building construction. A better earth retain technologies are required for high rise building construction, and the earth retains technologies applied in the selected cases are as follows: Steel Truss, Sheet piles, Secant piles, and Jet grouting wall.

4.3. *Analysis of Innovative Technologies adopted in Superstructure Phase*

Through a critical literature review, innovative technologies adopted in superstructure phase has been divided in to six (06) areas; i.e. Formwork, Hoisting and Working Platforms, Reinforcements, Concrete Work, Pumping, and Prefabricated Elements.

The literature identified that aluminium, fiber glass, plastic, crane operated climbing, system formwork (PERI system), and slip formwork, are used as innovative systems compared to the conventional timber/ plywood formworks. It could observe that Cases 1, 4, and 6, used aluminium formwork while other projects used plywood as formwork for general purposes. In addition, except Cases 5 and 6, all other projects have used system formwork as an advanced formwork system. Case 4 additionally used crane operated system formwork. One respondent from Case 5 stated that skilled workers can perform an equal work load in a lesser cost than with the use of system formwork.

Table 6 illustrates the findings of hoisting and working platforms, and depicts that working platforms are more popular than gondolas among the cases. It revealed that automated building construction systems (ABCS) are not yet practised, but Cases 1, 3 and 5 used semi-automated cranes during the construction. The interview personnel stated that the lifting weight and turning range were automatically controlled in these cranes. The luffing crane, which has ability to move horizontally and vertically, is more popular. In Case 3, CCTV cameras were located on top of the crane, which can be operated from the office. They were located to check the progress and ongoing work. The respondent of Case study 5 said that mobile cranes become a new trend, which can climb through core and work at top of the building.

Table 6: Innovative Technologies in Hoisting and Working Platforms

Innovative Technology	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**	**Case 8**	**%**
Gondola/Swinging Stage	√	X	X	X	√	√	X	X	37.5
Work platforms	√	X	X	√	√	√	X	X	50.0
Automated building construction system	X	X	X	X	X	X	X	X	0.0
Automated crane	√	X	√	X	√	X	X	X	37.5

Reinforcement bars area key material in high rise buildings. The study revealed that except Portable rebar tying tools, other types such as rebar cutter, reinforced bar bending machine, and Reinforced bar coupler in columns, have been used in all projects. Cases 1 and 7 used electrical bar bending machines and others used hydraulic bar bending machines, which have 3 times speed on average than manual. Moreover, the electrical portable rebar cutters were used instead of gas cutter. The respondents specified that bar couples in column becomes a popular technology, which reduced the lap length, and further it revealed that the cup lock scaffolding use 50% among these cases. The respondent in Case 3 stated that cup lock scaffoldings are speedy and need less labour for erecting and dismantling than conventional steel scaffolding.

A special concrete was used in high rise building construction, where self-compacting concrete and alternate for Portland cement concrete was commonly used. The projects that used self-compacting concrete (Cases 1, 2, 4, 5, and 7) identified that free compaction and high flow ability caused the popularity of self-compacting concrete in high rise building construction. The respondent of Case 4 said that self-compacting concrete is used for rebar in congested areas. Conversely, magnetically driven concrete and self-healing concrete are not practised well in the selected cases. However, light weight concrete was used in 75% of the projects. The Case 1 respondent indicated that reducing the structural weight of the building was the main aim of using light weight concrete. Carbon nano tubes are not used in these projects although they are a substitute for reinforced concrete. In addition, several cases used admixtures mixed concrete for specific purposes. Cases 1, 2, and 5 used ice mixed concrete to control the heat in concrete. Case 1 used accelerated admixture to speed up the hydrant of the concrete to speed erection. Case 3 used fly ash and silica fume for basement construction due to its high strength and water resist characteristics, while Case 5 used water proofing concrete as a water resistant purpose.

Table 7 present the findings of innovative technologies in concrete pumping systems. The findings emphasised that the stationary concrete pumps are the most popular type in these cases. Next was the truck mixture concrete pump. Case 4 used all three types of pumping systems, and its respondent said that pumping system need to be changed with the erected height of the building. According to his opinion, the truck mixture concrete pumps are the most suitable pumping method for the construction of foundation and basement. The stationary pumps are needed to pump concrete to a higher level. If the height could not be achieved by available stationary pumps, then the use of stage pumps becomes a necessity rather than changing to higher capacity stationary pumps. As stated by the respondents, the available equipment become ideal, and will impact the cost and time.

Table 7: Innovative Technologies in Pumping

Innovative Technology	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	%
Truck-mixture concrete pumps	√	√	√	√	X	√	√	√	87.5
Staged pumping	X	X	X	√	X	X	X	X	12.5
Stationary concrete pumps and booms	√	√	√	√	√	√	√	√	100.0

The next advanced technology was prefabrication elements, which have been used in 50% of the cases. Case 1 respondent stated that precast wall construction method “Eco-tec” is popular in Sri Lankan construction industry. It revealed that pre-tension concrete and contour crafting are not practised in the selected cases. Post-tension concrete elements are used in Cases 3 and 4. The respondent of Case 3 stated that the post-tension slabs are used due to less beam depth and optimum floor height with less thickness of slab. Therefore, in Case 3, the entire building received post-tension concrete slabs. However, Case 4 decided to adopt post-tension slabs for special requirements and thus, only one part adopted post-tension slabs to gain a large span with less columns. Cases 2 and 4 used sandwich panels as insulation. In Case 2, sandwich panels were used in the auditorium and to partition walls. The respondent of Case 4 explained that plastic spacers were used when placing structural precast element, because it facilitated perfect fixing.

4.4. Analysis of Innovative Technologies adopted in Finishes Phase

Table 8 illustrates the innovative technologies used for finishes work. According to the findings, power trowelling is the most popular floor finish. According to the respondent of Case 2, many high rise building projects tend to use power trowelling method due to less additional material, speed, and cost. Plastering machines and painting machines received 50%. Case 4 respondent explained that epoxy flooring was used for special requirements to gain an advanced finish. In addition, respondent of Case 3 stated that timber flooring to floor finishes and wall papers to wall finishes were applied. Case 5 used Wall claddings.

Table 8: Innovative Technologies in Finishes

Innovative Technology	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	%
Plastering machinery	X	√	X	√	√	X	√	X	50.0
Painting machines	√	X	X	√	√	√	X	X	50.0
Tiling machines	X	X	X	√	X	X	X	X	12.5
Epoxy flooring	√	X	X	√	X	X	√	X	37.5
Power Trowelling	√	√	√	√	√	√	√	√	100.0

4.5. Benefits and Challenges for Client and Contractor by using Innovative Technologies

The study identified identical benefits gained by the client and the contractor by using innovative technologies as follows:

- Time saving due to speed construction
- Cost reduction due to less wastage and less construction period
- Less additional material, labour, and equipment
- Proactive material covers more than one purpose
- High quality of work
- Less disputes between the parties due to proper communication
- Obtain optimum space as working space
- Special requirements can be fulfilled
- Waste reduction

On the other hand, challenges faced by client and contractor when using innovative technologies were identified through the opinions of respondents’:

- Higher initial cost premium
- Most of innovative plant and equipment are at higher costs
- Transport issues

It revealed that some innovative materials and plant required special permission to transport, because innovative materials and plant could not be categorized under existing categories in regulatory bodies. Therefore, it requires a special permit from authorities, and this process demand additional cost and time.

- Lack of operators or skilled labours and supervisors
- Innovative technologies are required for staff and labour training
- Insufficient suppliers and sub-contractors due to occasional usage of innovative plant and materials
- Heavy machinery requirements for several innovative technologies
- Need staff training, and that process need a longer period with additional costs

To adopt innovative technologies, it is pertinent to mitigate above challenges. Therefore, an organization needs to proceed after identifying internal and external impacts.

5. CONCLUSIONS

Most practising technologies were imported to local construction organizations from abroad, while some advanced technologies migrated with foreign organizations. The high technical and advanced technologies integrated with robotic are less practised in the construction industry. In addition, due to less skilled labour, some innovative technologies remain on the edge. Conversely, there is a possibility to apply those technologies in the construction industry with time. As the study revealed, innovative technologies could dominate the construction industry soon because the high rise buildings that can not be tackled through current practising technologies, are upcoming in Sri Lanka. Therefore, to survive and gain more benefits, it is necessary to adopt and encourage innovative technologies in local construction industry.

6. REFERENCES

Acuna, M. I. (2000). *Reducing time in the construction of high rise buildings.* Doctoral dissertation, Massachusetts Institute of Technology.

Ahn, H. Y., Pearce, R. A., & Wang, Y. (2013). Drivers and barriers of sustainable design and construction: The perception of green building g. *International Journal of Sustainable Building Technology and Urban Development, 4*(1), 35-45. doi:http://dx.doi.org/10.1080/2093761X.2012.759887

Allianz-Global-Corporate&Specialty. (2014). *Supertall Buildings Construction risk assessment in the 21st century.* Jonathan Tilburn, London: Allianz Global Corporate & Specialty.

Alshanbar, H. (2014). *Project Coordination Using Cloud-Based BIM Computing in Education.* Washinton: The building SMART alliance.

Arivazhagan, B. (2014). Automatic plastering machine. *Advanced Research in Electronics, Communication & Instrumentation Engineering and Development, 2*(2), 29-35.

Assaf, S., & Al-Hejji. (2006). Causes of delay in large cinstruction projects. *International Journal of Project Management, 24*(4), 349-357. doi:10.1016/J.ijproman.2005.11010

Benmansour, C., & Hogg, K. (2-4 September 2002). An investigation into the barriers to innovation and their relevance within the construction sector. In D. Greenwood (Ed.), *18th Annual ARCOM Conference. 2.* Northumbria: University of Northumbria.

Bock, T. (1998). *Automation and Robotics in Building Construction.* Munich,Germany: technische University.

Chen, J., Wang, J., & Jin, W.-l. (2016). Study of magnetically driven concrete. *Construction and Building Materials, 121*(1), 53-59.

Choi, Y., Kim, D. C., Kim, S. S., NAm, M. S., & Kim, T. H. (2013). Implementation of noise-free and vibration-free PHC screw piles on the basis of full-scale tests. *Journal of Construction Engineering and Management, 139*(8), 960-967.

Construction Industry in Sri Lanka. (2011). *Construction Industry in Sri Lanka.* Colombo: ICRA Lanka and IMaCS.

Creswell, J. W. (2014). *Research design : qualitative, quantitative, and mixed methods approaches.* (4, Ed.) New Delhi, India: SAGE Publications India Pvt. Ltd.

Dahlin, T., & Yngvesson, M. (2014). *Construction Methodology of Tubed Mega Frame Structures in High Rise Buildings.* Stockholm, Sweden: Master Thesis in Concrete Structures, Royal Institute of Technology.

Denagama, J., & Hadiwattege, C. (2013). *Development Supportive Novel Trends and Practices for Construction Sector.* Colombo: Department of Building Economics, University of Moratuwa, sri Lanka.

Dossick, C. S., & Simonen, K. (2014). *Integrated AEC studio: iteration between analysis and design for interdisciplinary learning.* Washington: The building SMART alliance.

Dubois, A., & Gadde, L. (2002). The construction industry as a loosey coupled system:Implications for productivity and innovation. *Construction Management and Economics*, *20*(7), 621-631. doi:10.1080/01446190210163543

Egan, J. (1998). *Rethinking Construction.* London: Department of the Environment, Transport and the Regions.

Haowen, Y. (2015). Innovative Technologies and their Application on Construction of a 100-Plus-Story Skyscraper. *International Journal of High-Rise Building, 4*(3), 161-169.

Harrison, A. J. (2013, March). Low carbon cements and concrete in modern construction. In UKIERI. *Concrete Congress–Innovations in Concrete Construction*, pp. 723-746.

HING, L. C. (2006). *Construction technology for high rise buildings in Hong Kong* . Queensland: Doctoral dissertation, University of Southern Queensland.

Hirlekar, R., Yamagar, M., Garse, H., Vij, M., & Kadam, V. (2009). Caebon nanotubes and its application: a review. *Asian Journal of Pharmaceutical and Clinical Research, 2*(4), 17-27.

Hu, L. (2016). Analysis on Technological Innovation of Civil Engineering Construction. *Engineering, 8*(5), 287-291.

Ikeda, Y., & Harada, T. (2006). Application of the automated building construction system using the conventional construction method together . *23rd International Symposium on Automation and Robotics in Construction.* Tokyo, Japan.

Iwiss. (2008). *Electric rebar cutting and bending tools.* Iwiss Electric Co.Ltd. Retrieved from www.iwiss.com

Jonkers, H. M. (2011). *Bacteria-based self-healing concrete.* Heron, 56 (1/2).

Kang, T. K., Nam, C., Lee, U. K., Doh, N., & Park, G. T. (2011). Development of robotic-crane based automatic construction system for steel structures of high-rise buildings. *ISARC* (pp. 670-671). Seoul, Korea: ISARC.

Kavilkar, R., & Patil, S. (2014). Study of high rise residental building in Indian cities(A case study-Pune city). *International journal of Engineering and Technology, 6*(1), 86-90.

Khoshnevis, B. (2004). Automated construction by contour crafting -related robotics and Information Technology. *Automation in Construction, 13*(1), 5-19.

Kildienė, S., Zavadskas, E. K., & Tamošaitienė, J. (2014). Complex assessment model for advanced technology deployment. *Journal of civil engineering and management, 20*(2), 280-290. doi:doi:10.3846/13923730.2014.904813

Krishnan, L., Karthikeyan, S., Nathiya, S., & Suganya, K. (2014). Geopolymer concrete an eco-friendly construction material. Magnesium. *International Journal of Research in Engineering and Technology, 1*(1), 164-167.

Kyjakova, L., Mandicak, T., & Mesaros, P. (2014). Modern Methods of Constructions and Their Components. *Journal of Engineering and Architecture, 2*(1), 27-35.

Ling, F. (2003). Managing the implementation of construction innovations. *Construction Management And Economics, 21*(6), 635-649. doi:10.1080/0144619032000123725

Lloret, E., Shahab, A., Linus, M., Flatt, R., Gramazio, F., Kohle, M., & Langenberg, S. (2015). Complex concrete structures merging existing casting techniques with digital fabrication. *Computer-Aided Design, 60*, 40-49. doi:http://dx.doi.org/10.1016/j.cad.2014.02.011

McCuen, & Tamera. (2014). *The Challenges of Advancing BIM in the Curriculum while Addressing Current Accreditation Standards for Construction.* Washinton: The buildingSMART alliance.

Mehta, P. K. (1999). Advancements in concrete technology. *Concrete International -Detroit, 21*(1), 69-76.

Miyakawa, H., Ochiai, J., Oohata, K., & Shiokawa, T. (2000). *Application of Automated Building Construction System For High Rise Office Building.* isarc 2000-085_WB2.

Naguyen, T., & Chileshe, N. (2015). Revisiting the critical factors causing failure of construction projects in Vietnam . *Built Environment Project And Asset Mnagement, 5*(4), 398-416. doi:10.1108/bepam-10-2013-0042

Naji, B., Cottier, J. S., & lyons, R. (2005, May 17). *United States Patent No. US 6,893,751 B2.*

Navon, R., Rubinovitz, Y., & &Coffler, M. (1998). Rebar Computer Aided Design And Manufacturing. *Computer-Aided Civil and Infrastructure Engineering, 10*(6), 155-162.

Outokumpu. (2013). *Stainless Steel Reinforcing Bar Couplers.* Sheffield, United Kingdom: Outokumpu Stainless Ltd. Retrieved from www.outokumpu.com

Pan, Y., & Hou, L. (2016). Lifting and parallel lifting optimization by using sensitivity and fuzzy set for an earthmoving mechanism. (pp. 1-12). proceeding of the Institution of Mechanical Engineering. doi:DOI: 10.1177/0954407016660454

Prasanth, S. (n.d.). *Aluminium Form Work System.* Chenna: Grand Edifice Developers.

Puddicombe, M. (1997). Designers and Contractors: Impediments to Integration. *Journal Of Construction Engineering And Management, 123*(3), 245-252. doi:10.1061/0733-9364(1997)123:3(245)

Putzmeister. (2010). *Putzmeister Concrete Technology.* Germany: Putzmeister Concrete Pumps GmbH .

Richard, K. (1962). *Fiberglass Form Work.* , The Aberdeen Group.

Rosenberg, N. (2004). *Innovation And Economic Growth.* Stanford University, Economics. California: Stanford University.

Sakamota, S., & Mitsuoka, H. (1994). Totally Mechanized Construction System for High-Rise Buildings (T-UP System). In S. Sakamota, & A. D. Chamberlain (Ed.), *Automatic and Robotics in Construction XI* (p. 730). Boston: Newnes,2012.

Sandelin, C., & Budajev, E. (2013). *The Stabilization of High-rise Buildings: An Evaluation of the Tubed Mega Frame Concept.* Uppsala: Department of Engineering Science, Applied Mechanics, Civil Engineering, Uppsala University.

Schexnayder, C. J., & David, S. A. (2002). Past and Future of Construction Equipment-Part IV. *Journal of construction engineering and management, 128*(4), 279-286.

SGB-Group. (2005). *Cup Lock Scafold User Guide.* Leatherhead, Surrey: SGB Services Limited. Retrieved from www.sgb.co.uk

Shin, Y., Kim, T., Cho, H., & Kang, K. I. (2012). A formwork method selection model based on boosted decision trees in tall. *Automation in Construction, 23*(1), 47-54.

Slaughter, E. (1998). Models of Construction Innovation. *Journal Of Construction Engineering And Management, 124*(3), 226-231. doi:10.1061/(asce)0733-9364(1998)124:3(226)

Tatum, C. B., Vorster, M., & Klingler, M. (2006). Innovations in earthmoving equipment: new forms and their evolution. *Journal of construction engineering and management, 132(9), 987-997., 132*(9), 987-997.

Thapa, C., Dhakal, D. R., & Dhakal, A. (2013). Construction Techniques and Demand Of High Rise Building In India. *International Journal of Emerging Trends in Engineering and Development, 2*(3), 46-51.

Thillairaja, S., Varun Yadav, K., VelMuruga, G., Venkatesan, S. P., Prabhakar, K., & Kumar, R. (2015). Reinforced bar bending machine. *Australian Journal of Basic and Applied Sciences, 9*(10), 290-294. Retrieved from www.ajbasweb.com

Vähä, P., Heikkilä, T., Kilpeläinen, P., Järviluoma, M., & Heikkilä, R. (2013). *Survey on automation of the building construction and building products industry.* Oulu: JULKAISIJA – UTGIVARE.

Väha, P., Heikkilä, T., & Kilpeläin, P. (2013). Extending automation of building construction — Survey on potential. *Automation in Construction, 36*(1), 168-178.

Vennstrom, A., & Eriksson, P. (2010). Client perceived barriers o change of construction process. *Construction innovtion: information, process, management, 10*(2), 126-137. doi:10.1108/14714171011037156

Vivian, W., Ivan, W. F., & Michael, C. (2015). Best practice of prefabrication implementation in the Hong Kong public and private sectors. *Journal of Cleaner Production, 109*(1), 216-231.

Warszawski, A., & Navon, R. (1998). Implementation of Robotics in Building: Current Status and Future Prospects. *Journal Of Construction Engineering And Management, 124*(1), 31-41. doi:10.1061/(asce)0733-9364(1998)124:1(31)

Wells, J. (1985). *The construction industry in the context of development* (Vol. 8). London: Pegamon Press Ltd.

Winch, G. (2003). How innovative is construction? Comparing aggregated data on construction innovation and other sectors – a case of apples and pears. *Construction Management And Economics, 21*(6), 651-654. doi:10.1080/0144619032000113708

Yehia, S., Douba, A., Abdullahi, O., & Farrag, S. (2016). Mechanical and durability evaluation of fiber-reinforced self-compacting. *Construction and Building Materials, 121*(1), 120-133.

Yu, K., Guan, Z. J., Cheung, T., T. T., & Lo, T. (2000). Applied Radiation and Isotopes. *Light weight concrete: 226Ra, 232Th, 40K contents and dose reduction assessment*, *53*(6), 975-980.

FACTORS AFFECTING SUSTAINABLE DESIGN IN ARCHITECTURE: PERCEPTIONS FROM TURKEY

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ABSTRACT

A significant portion of the scholarly contributions to the sustainable architecture debate falls into the 'eco-technic' stream of thought with its considerable emphasis on efficiency and high-technology as the solutions of environmental problems. This perspective, however, can be criticised for ignoring the interaction of a large set of contextual factors that surround the ongoing debate. As part of a research study which aims to develop a prediction model for the pro-environmental behaviours of architects as practicing professionals, a questionnaire survey was designed and delivered to the members of Istanbul Chamber of Architects. The measurement instrument had an open question: What are the factors that influence (hinder or facilitate) the development of sustainable solutions in architecture? Around 120 architects responded and these responses were qualitatively analyzed to identify the factors that influence their sustainability-related decisions. The findings suggest that while the client-related, economic and legal factors are especially critical to achieve targets, the adoption and implementation of sustainable solutions in the building industry require a thorough understanding of the interactions of individual, organization, inter-organization, and country-level factors. Decision makers who are responsible for designing sustainability policies and steering mechanisms in the building industry can be the main beneficiaries from a better understanding of such interactions.

Keywords:*Architects; Building Industry; Sustainable Architecture; Sustainable Design; Turkey.*

1. INTRODUCTION

Sustainability concept may have different meanings for different stakeholders. However, it appears reasonable to highlight the common denominators of the concept (Berardi, 2013:73): It is *time dependent*; so the way we understand sustainability is flexible according to the availability of knowledge at any given time; it is *space-dependent*, so understanding the local context of sustainability discussion is indispensable; it is *domain-specific*, so people who behave environmentally at home may not be that sensitive, for example, in their purchasing or transportation decisions; and finally, sustainability concept has *interpretative flexibility*, so a pluralistic approach is needed to understand and address the perceptions of different stakeholders.

The sophisticated nature of the sustainability concept is one of the sources of conflicting perspectives and multiple interpretations of different stakeholders in the building industry, which tend to make sustainable building (SB) suit their peculiar needs. On a practical level, SB requires the use of innovative methods, tools and materials in building production; an improved interaction of stakeholders in an integrative way and the use of new management implementation tools, including also the new ways of certification and quality control procedures (Rekola *et al*, 2012:79-80). Green building certification systems such as the US Green Building Council's Leadership in Energy and Environmental Design (LEED) and the Building Research Establishment Environmental Assessment Method (BREEAM) accentuate the major goals of SB (Chong *et al*, 2009:144): reduced carbon footprints; ecological and environmental protection; creating a healthy indoor and outdoor

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environment; reduced water usage; achieving energy efficiency; eliminating environmentally harmful materials; improving resource efficiency, and conserving resources of land and raw materials. An overwhelming majority of the scholarly contributions to the sustainability debate appears to fall into this 'eco-technic' stream of thought with its considerable emphasis on efficiency and high-technology as the solutions of environmental problems. This perspective, however, can be criticized for ignoring the contextual factors that surround the sustainability-oriented initiatives. In Turkey, for example, while this paper is being written, there is a hot debate on many large infrastructure projects such as 'Kanal Istanbul', which has an ambitious goal of connecting The Black Sea to The Marmara Sea through a channel and The Yavuz Sultan Selim Bridge' - the third suspension bridge over the Bosporus to the north of the present ones- which was taken into operation on 26th August, 2016. These gigantic projects are functioning as a political litmus paper in the Turkish society, between the right and left-wing politicians and citizens: The sharp discrepancy is between those who see these investments as the *sine qua non* for achieving economic growth, and those, including the Chamber of Architects (CAT) and many other professional organizations and NGOs, which are extremely concerned about the irreversible impacts of these investment projects on the natural and built environment in the long run. It is argued in this paper argues that the technical aspects of the sustainable architecture debate cannot be isolated from the surrounding factors.

Based on qualitative data from about 120 practicing architects, this paper aims to understand the factors that affect the ongoing debate on sustainability, from the perspectives of architectural designers, who deserve attention in terms of their special relationships with the clients and the associated capacity to specify the end-product with desired level of sustainable outcomes. After a review of the barriers to sustainability in the building industry and a short summary of the major streams of thought in the sustainable architecture debate, the paper presents the findings of the empirical study.

2. BARRIERS TO SUSTAINABILITY IN THE AEC INDUSTRY

A diverse set of barriers to sustainable building (SB) have been reported in the literature, where many researchers agree that the fragmented structure of the building industry where stakeholders have different priorities, visions, ideas and technical knowledge base, makes it difficult to develop a shared sustainability agenda and achieve targets in an integrated way. This hinders the successful delivery of the sustainability-oriented projects because they are generally more complex relative to the traditional projects due to the level of collaboration, networking and knowledge exchange they require in the process (Klotz and Horman, 2010:595; Hakkinen and Belloni, 2011:244), where interpersonal skills (Magent *et al*, 2009:62), and the coercive interplay between technical subsystems may become critical (Kendall, 1999:5). However, the traditional project delivery system, rooted in the rise of specialized disciplines in the 1970s (Magent *et al*, 2009:62), does not allow an early collaboration among the stakeholders, resulting in a loss of possibilities and right design options (Hakkinen and Belloni, 2011:244). Consequently, AEC professionals encounter difficulties to access critical value-added sustainability knowledge. For example, design and construction know-how is left to the construction phase, while maintenance and replacement of building elements are left to the facility managers (Chong *et al*, 2009:144). Construction organizations cannot share their expertise on the planning and cost estimation processes (Hakkinen and Belloni, 2011:244). There are signs that the new project delivery systems (e.g., the Integrated Project Delivery) and the associated collaboration platforms (e.g., the Building Information Modeling) can provide valuable opportunities to achieve an integrated project process with complex design analyses and material/system selection (Hakkinen and Belloni, 2011:244).

Environmental and social concerns rarely counterbalance cost factors in the industry since the building projects demand a huge financial commitment, which makes it difficult for companies and clients/owners to divert attention from the risks of cost and time overruns (Chong *et al*, 2009:151). Fear of additional costs, expensive design and construction, long payback periods (Dong and Wilkinson, 2007:278) and the methodological difficulties to quantify positive outcomes (e.g. increased market value or reduced operation costs) from sustainable building prevent clients from using their influence on the development of sustainable solutions (Hakkinen and Belloni, 2011:242). Low demand pushes the prices of sustainable products and make them less attractive in the short run. High costs of buildings raise the perceived risk of sustainable solutions, which often have innovative aspects, and lead to a phenomenon often referred to as conservatism by many scholars. According to Hakkinen and Belloni (2011:240-247), lack of experience and comprehensive information about new solutions result in a resistance to new technologies, which necessitate additional effort on the suppliers' side to provide reliable information to the market to reduce uncertainty.

Implementation of sustainable solutions requires a significant shift in the knowledge base of the building industry, as they generally require innovation, new knowledge and learning effort (Hakkinen and Belloni, 2011:244). From curriculum revisions in higher education and continuing professional development programs to revisions/development of codes and standards, and to a better collaboration between academia and industry, the building industry needs to explore more efficient means to convert the sustainability-related knowledge into industrial practice (Chong *et al*, 2009; Dong and Wilkinson, 2007; Hakkinen and Belloni, 2011:240). Access to this knowledge can be especially critical in the residential building sector (Hakkinen and Belloni, 2011:245), which is dominated by small and medium enterprises (SMEs) with relatively limited resources and management capacity. The lack of or wrong types of policies, steering mechanisms and the associated instruments can hamper the dissemination of sustainable practices (Chong *et al*, 2009:152; Hakkinen and Belloni, 2011:242).

There appears a consensus on the dominant role of clients: They are the actors who demand innovative solutions, take financial risks, and facilitate the transformation of supply chain towards better collaboration and integration. To be able to fulfill such roles, however, their general level of knowledge on sustainability should be increased significantly. Governmental and local authority organizations are thought to have additional responsibilities in this transformation process not only as the clients of exemplary building projects, but also as the developers and disseminators of sustainability norms, methodologies, metrics, specifications and reliable information via the public procurement and tendering systems for both new buildings and the existing building stock (Hakkinen and Belloni, 2011:240-249). The following section will narrow the topic to the role of architectural designers.

3. DEBATE ON SUSTAINABLE ARCHITECTURE

Hopwood *et al* (2005:41) differentiate between three broad views on sustainable development: that it can be achieved within the present structures by maintaining *status quo*; that a fundamental reform is necessary to achieve sustainability without disrupting existing arrangements (the *reformist* approach); and that a radical transformation is needed to change the economic and power structures in the society to achieve sustainability (the *transformative* approach). After a comprehensive synthesis, Guy and Farmer (2011) identify various streams of sustainability thought (or "typologies of environmental logic") in the architecture literature, which can be distinguished from each other according to the level of emphasis they place on technology; culture and values; aesthetics; health and social factors. Based on Guy and Farmer's typologies, it seems reasonable to contend that the majority of the scholarly contributions to the sustainable architecture debate in the building industry put significant emphasis on efficiency, innovation and high-technology as the solutions of environmental problems. Researchers from this eco-technic stream of thought have addressed different aspects of sustainable design such as the building management systems; energy and water efficiency; material usage; recycling, amongst others (Bunz *et al*, 2006:34).

Overemphasis on technology, however, may sometimes be at the expense of an adequate assessment of the contextual factors that surround the sustainable architecture debate. Keitsch (2012:142-143) highlights that "*the call to examine practices and methods as well as values and norms is growing louder...*" accompanied by a call for interdisciplinary cooperation and teamwork to address the complexity of problems. Sustainable solutions require a "*thorough understanding of the connections between interconnected subsystems to create innovative solutions*" (Rekola *et al*, 2012:78) and an exchange of functional competencies among various stakeholders (Magent *et al*, 2009:63). Emerging project delivery systems of the day (e.g., the Integrated Project Delivery) point not only to a paradigm shift in terms of doing business in the industry, but also to the reshaping of power relationships in a new era, to which the architects need to adapt themselves. Hakkinen and Belloni, (2011:245) argue that designers' self-confidence is significantly reduced when they are expected to develop sustainable solutions. This might be partly related to the fact that "*the dominant ideology in architectural circles and in architectural education continues to follow the emphasis on the singular building expressing the architect's and client's wills rather than on the 'cultivating of ordinary buildings in a continuous urban fabric that serves as a setting for the special building*" (Kendall, 1999:2). Additionally, the difficulties concerning the access to sustainability-related data and the lack of automatic calculation procedures and tools, especially in the early design stage, are often highlighted among the barriers to sustainable design solutions (Hakkinen and Belloni, 2011:245-246).

4. METHOD

A research was designed to investigate the factors that influence the pro-environmental behaviors of architects as professional individuals considering that an adequate understanding of these factors could be a valuable input for the design of efficient intervention programs aimed at behavior changes via structural and/or informational strategies. As part of this larger research study, a questionnaire was designed and delivered to the members of Istanbul Chamber of Architects (CAT) in collaboration with CAT. In addition to the closed questions related to the pro-environmental behaviors of architects, the questionnaire included an open question: "*What are the factors that influence (hinder or facilitate) the development of sustainable solutions in architecture?*" So that the authors aimed to describe the local environmental context of the sustainability debate in Turkey and compare it to the general literature to achieve a sound interpretation of the quantitative evidence. The authors initially considered choosing a stratified sampling strategy, however, the CAT did not have a full and up-to-date list of architects with detailed demographic characteristics such as the marital status; education level; employment status; and others. Consequently, the link of the digital questionnaire was sent by the CAT to around 18,000 members in Istanbul, and those interested were invited to fill out. 123 architects, out of 280 who filled out the questionnaire, were responsive to the open question and they provided qualitative feedback. Table 1 presents the composition of the respondents. Although this composition was not an outcome of a stratified sampling strategy, the survey respondents appeared reasonably balanced in number according to their gender, marital status, formal education and income levels. Qualitative content analysis was conducted to analyze their responses to code the textual material to provide a meaningful reading of the content.

Table 1. Composition of Sample

Variables		**Number of respondents**	**%**	**Mean**	**Median**	**Standard deviation**
Gender						
	female	78	63	-	-	-
	male	45	37			
Age				35.51	31.00	11.68
Marital status						
	single	66	54	-	-	-
	married	57	46			
Formal education level (degree)						
	undergrad	66	54	-	-	-
	grad	57	46			
Income (Turkish Lira – TL)						
	<2,000	6	4.87	-	-	-
	2,000-3,999	56	45.52	-	-	-
	4,000-5,999	36	29.26	-	-	-
	6,000-9,999	18	14.64	-	-	-
	>10,000	7	5.70	-	-	-
Position in the company						
	employee	98		-	-	-
	employer	25		-	-	-
Company size (No. of employees)				25.00	10.00	172.33

5. FINDINGS

Following a qualitative content analysis, which included several rounds of coding effort by the authors, a total of 36 themes (factors) from the textual material were classified into four levels of analysis, including the *individual* level; the *organizational* level; the *industry/inter-organization* level; and the *country* level. Although the frequencies of the responses of the architectural designers may not be the primary focus of interest in a qualitative content analysis, Figure 1 below gives an idea about where the majority of the concerns of the designers tend to cluster. Figure 1 suggests that the demand for sustainable solutions from the environmentally sensitive clients, who are ready to bear/share the cost of these solutions; governmental/legal factors which may correspond to various barriers or facilitators; and the level of access to knowledge and expertise concerning sustainable solutions at various levels are perceived as the major factors that shape the sustainable architecture agenda in Turkey.

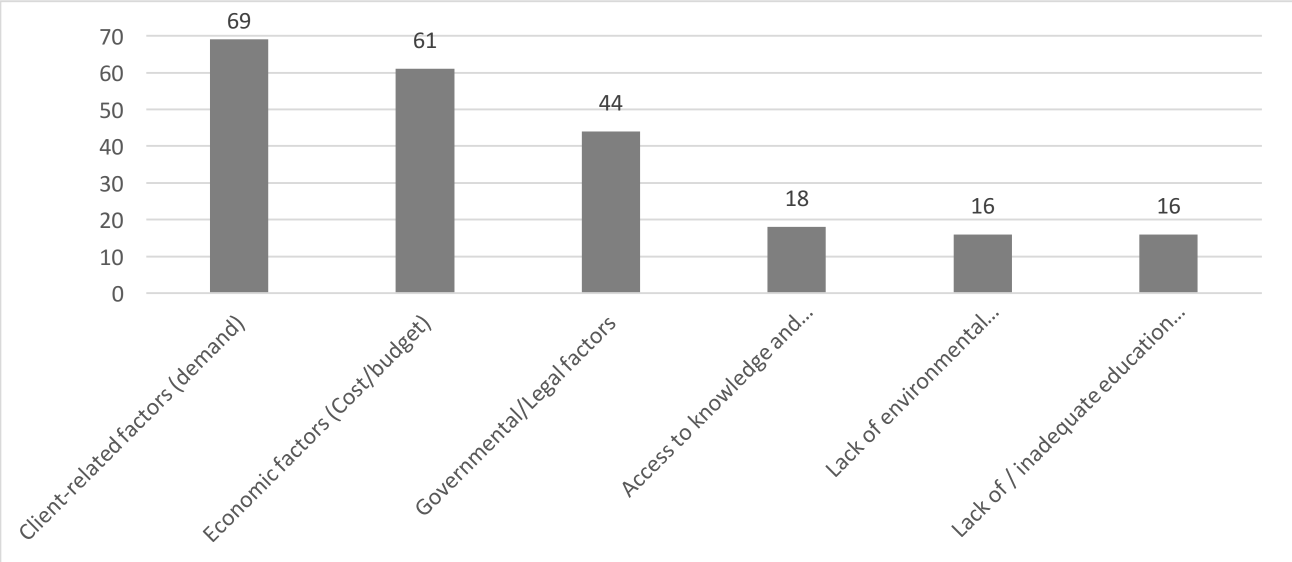

Figure 1: Frequency of Factors that Affect Sustainable Design Solutions

[a]*The vertical axis shows the number of respondents*

Table 2 presents a more inclusive summary of the qualitative evidence. As Table 2 shows the designers place considerable emphasis on the industry and country-level factors, while less emphasis is placed on the individual and organization-level factors. Although many of the factors in Table 2 have many commonalities with the globally shared concerns of the building industry, various factors with strong local context deserve particular attention, recalling that 'spatial dependence' (local interpretation) is amongst the common denominators of the sustainability concept (Berardi, 2013:73).

Many architects argue that the main character of the sustainability debate in Turkey is significantly shaped by a set of country-level factors (sub-items under 4.1 and 4.2 in Table 2). The lack of a political will to develop a national sustainability agenda, coupled with the short-term governmental policies especially in the housing and energy sectors, which fuel overconsumption patterns, and the prevailing development models which merely focuses on economic growth at the expense of social rights and in favor of special interest groups, are amongst the obstacles that hinder the adoption and dissemination of sustainable practices in the building industry. According to designers, factors such as the incompetence of public officials to inspect design projects which incorporate innovative elements; the conservativeness of the development law plan which favors individual building solutions, rather than their coherence in an urban fabric; the lack of national standards and building codes which could ease the contemporary use of traditional building techniques and materials, are amongst the intrinsic results of the lack of a sustainability-oriented political agenda.

> *Overconsumption patterns in the country is an obstacle to sustainability* (29 years old; male; single; master’s degree; 5 years of sector experience)

> *Current governmental strategy on energy is an obstacle to developing sustainable design solutions* (29 years old female with an undergraduate degree and 5 years of professional experience)

> *Especially in the public projects, officials without adequate* [technical] *knowledge intervene the process and they negatively influence the projects by putting forward cost issues* (45 years old female with a master’s degree and 25 years of professional experience)

> *We can develop true solutions by developing a national strategic plan* [on sustainability] *as early as possible* (72 years old male with a master’s degree and 43 years of professional experience)

> *Current building regulations and floor area ratios in Turkey are creating dense architectural spaces which give way to overconsumption* [of resources] *and which are too far from being sustainable. It is difficult to talk about*

> *sustainability* [under these circumstances]. *We can easily observe that green certification systems of many buildings are the means to cover rent seeking* [behavior] (28 years old female with master's degree and 3 years of professional experience)

A relatively small number of survey respondents accentuate the lack of a participative and decentralized decision making culture (item 4.2.13 in Table 2), which inevitably results in an inadequate number of local initiatives that are targeted at sustainable design solutions.

> *The political will is against the participation of professional organizations in [sustainability-related] decision making processes. Non-governmental organizations should counterbalance those who enjoy abnormal profits. Those who live in urban areas should have a voice in the management* (56 years old male with an undergraduate degree and 56 years of professional experience)

> In the face of a campaign to discredit architects, we should tell the society that architecture is important. The government sees architects as barriers to its political targets and tries to efface its influence on the society (43 years old male with a master's degree and 20 years of experience)

The respondents point also to the role of various country-level factors that are drivers for a positive change. Amongst these are the awareness building/raising campaigns through the mass media and the governmental initiatives (items 4.1.2 and 4.1.3 in Table 2); the legal arrangements which mandate sustainable solutions – such as the energy efficiency law which was put into effect in 2007 (item 4.2.5 in Table 2); and the procurement of public buildings via design competitions which facilitate the development of sustainable solutions (item 4.2.9 in Table 2). Architectural designers put also a significant emphasis on the positive influence of a steadily expanding knowledge base regarding sustainable solutions both at industrial/inter-organizational and individual levels, which help reduce the perceived risk of sustainable building (SB) practices with technologically innovative elements (items 1.2 and 3.1 in Table 2). The sustainable products portfolio that is expanding steadily in recent years; the ease of access to the technical consultancy services of suppliers and the digital corpus of SB solutions (items 1.2.3 and 3.1.1 in Table 2); the increasing number of exemplary projects in the building market ('trial-by-others') (item 1.2.2 in Table 2) are amongst the factors that enhance the industrial and individual knowledge base. While 'trial-by-other' is a critical mechanism for the dissemination of SB practices, 'failures of others' may have an opposite effect:

> *There are misguided clients who could not get satisfactory results from sustainable practices. I think some of the* [leading?] *architecture companies which perceive sustainable design only as a marketing strategy, without an understanding of sustainability principles, are responsible for this* (29 years old male with an undergraduate degree and 6 years of professional experience)

However, SB debate has a systemic nature in a project-based industry, where business and social networks are quite influential on the adoption and implementation of SB solutions:

> *...lack of knowledge of business partners such as mechanical, electrical and structural designers* (29 years old female with a master's degree and 8 years of experience)

At the organizational level, especially the early-career architects have pointed to the role of involvement in organizational decision making, as a factor which may facilitate or hinder their capacity to implement the SB solutions (item 2.2 in Table 2).

> *Sustainable design solutions are not valued in my work environment. The only way to put ideas into practice is to be a managing partner in the company...Developing sustainable solutions and putting them into practice could be easier in a companies which have supportive [organizational] climate. What really matters however is to have [decision making] authority in such organizations* (27 years old female with an undergraduate degree and 2 years of professional experience)

In addition to the factors listed in Table 2, majority of the respondents agree on the decisive role of the knowledgeable, open-minded and environmentally sensitive clients. Overall, qualitative evidence suggests that sustainable design solutions in the AEC industry are shaped by the multiple configurations of many factors which continuously interact with each other at different levels of decision making. Accordingly, it seems reasonable to contend that the sustainable architecture debate cannot be isolated from the surrounding context.

Table 2. Summary of Qualitative Content Analysis

1. Individual-level factors	**List of factors**	**Influence (+ / -)**
1.1. Habitual Behaviour/ Conservatism	1.1.1. Architects' reluctance to leave conventional solutions/ practices	-
1.2. Professional knowledge base	1.2.1. Previous professional experience with SB (e.g., involvement in overseas projects)	+
	1.2.2. Trial-by-others (access to the experience of others)	+
	1.2.3. Access to information on sustainable practices (e.g., Internet; digital databases and publications; information on best practices; dissemination activities such as conferences and seminars)	+
	1.2.4. Academic work (e.g., post-graduate study on sustainable solutions)	+
	1.2.5. Professional development activities	+
2. Organization-level factors	**List of factors**	**Influence (+ / -)**
	2.1. Environmental awareness and consciousness of decision makers in companies	+
	2.2. Involvement in decision making	+
	2.3. Inadequate time left to designers to engage in professional development regarding sustainable design solutions	-
3. Industry-level factors /	**List of factors**	**Influence (+ / -)**
3.1 Industrial knowledge base	3.1.1. Access to technical consultancy services (e.g. Individual experts or manufacturers)	+
	3.1.2. Technical know-how in the market (e.g., availability of qualified labour and the competency of contractors)	+
	3.1.3. Existence of innovative companies which demonstrate the benefits from sustainable practices (Trial-by-others) and reduce the perceived risk of sustainable solutions.	+
	3.1.4. Systematic approach of green building certification systems	+
	3.1.5. Collaboration between industry and academia	+
3.2 Structural characteristics of the building industry	3.2.1. Cost-based nature of competition in the building industry	-
	3.2.2. Fragmentation of the industry (e.g., lack of cooperation among business partners/stakeholders; lack of agreement on the definition of sustainability)	-
	3.2.3. Short design processes which hinder the development of sustainable solutions	-
3.3 Economic factors	3.4.1. Inability to demonstrate the tangible benefits from adopting sustainable practices (i.e. Cost benefit analysis, LCA, raising sales prices)	-
	3.4.2. Declining costs of sustainable solutions in relation to expanding portfolio of sustainable products in the market	+
4. Country-level factors /	**List of factors**	**Influence (+ / -)**
4.1. General knowledge base	4.1.1. Lack of emphasis placed on sustainability and the way it is taught in the education system at all levels (e.g., the lack of innovative methodologies to teach sustainable solutions)	-

	4.1.2. Media channels and campaigns that focus on environmental problems and build/raise sensitivity in the society (e.g., they ease the marketing of sustainable solutions to the clients)	+
	4.1.3. Governmental initiatives which build/ raise environmental awareness	+
4.2. Policies and steering mechanisms	4.2.1. Lack of environmentally-sensitive urban planning policies and implementation tools for highly populated urban areas	-
	4.2.2. Lack of intervention strategies which are specifically targeted at clients/end-users	-
	4.2.3. Lack of a national strategic agenda on sustainability	-
	4.2.4. Low level of investment on infrastructure for waste management and recycling facilities	-
	4.2.5. Governmental policies and legal arrangements which mandate sustainable solutions (e.g. Energy efficiency)	+
	4.2.6. Lack of support of municipalities and the complicated bureaucratic processes	-
	4.2.7. Lack of national standards on sustainable practices	-
	4.2.8. Lack of building codes which support sustainable practices	-
	4.2.9. Design competitions held by public clients that facilitate the development of sustainable solutions as part of procurement systems	+
	4.2.10. Lack of/inadequate use of financial instruments (sanctions and incentives), especially in the residential building sector, where the clients are relatively more conservative	-
	4.2.11. Inadequate research and development budgets for the development of sustainable solutions	-
	4.2.12. Governmental policies that fuel capitalist overconsumption patterns	-
	4.2.13. Nature of decision making regarding environmental policies (e.g., lack of decentralized and participative decision making, resulting in inadequate number of local initiatives)	-
	4.2.14. Government’s negative attitude towards professional organizations (e.g., campaigns to discredit architectural profession)	-

6. CONCLUSIONS

Sustainable solutions in the building industry are often the outcomes of the complex interactions between individual, organizational, industrial and country factors. Although the dissemination of technical knowledge regarding sustainable solutions at different levels has a positive impact in terms of reducing the risk perception of individuals, organizations, as well as of the building industry as a whole, we need a better understanding of the role of the contextual factors that surround the technical aspects of the sustainable architecture debate. This debate cannot be isolated from 'The Big Picture', in Turkey or elsewhere, since the success of various types of structural intervention strategies, targeted at 'changing the circumstances under which sustainability-oriented choices are made', is dependent on our collective ability to reach a consensus on the urgency of environmental problems, take political action to strength participative decision making at all levels, and build/raise awareness in the clients and the general public about the massive impact of the building industry on the natural and built environment.

7. REFERENCES

Berardi, U., 2013. Clarifying the new interpretations of the concept of sustainable building. *Sustainable Cities and Society*, 8(2013), 72-78.

Bunz, K.R., Henze, G.P. and Tiller, D.K., 2006. Survey of Sustainable Building Design Practices in North America, Europe, and Asia. *Journal of Architectural Engineering*, 12(1), 33-62.

Chong, W.K., Kumar, S., Haas, C.T., Beheiry, S.M.A., Coplen, L. and Oey, M., 2009. Understanding and Interpreting Baseline Perceptions of Sustainability in Construction among Civil Engineers in the United States, *Journal of Management in Engineering*, 25(3), 43-154.

Dong, B. and Wilkinson, S., 2007. Practitioner perceptions of sustainability in the Building Code of Australia, in AIBS 2007: Proceedings of the Australian Institute of Building Surveyors (AIBS). In: *2007 International Conference,* AIBS, Sydney, N.S.W., pp. 272- 288.

Guy, S. and Farmer, G., 2001. Reinterpreting Sustainable Architecture: The Place of Technology. *Journal of Architectural Education*, 54(3), 140-148.

Hakkinen, T. and Belloni, K., 2011. Barriers and drivers for sustainable building. *Building Research and Information*, 39(3), 239-255.

Hopwood, B., Mellor, M. and O'Brien, G., 2005. Sustainable development: mapping different approaches. *Sustainable development*, 13(1), 38-52.

Keitsch, M., 2012. Editorial: Sustainable Architecture, Design and Housing. *Sustainable Development*, 20(issue): 141–145.

Kendall, S., 1999. Open Building: An Approach to Sustainable Architecture, *Journal of Urban Technology*, 6(3), 1-16.

Klotz, L. and Horman, M., 2010. Counterfactual Analysis of Sustainable Project Delivery Processes. *Journal of Construction Engineering and Management*. 136(5), 595-605.

Magent, C.S., Korkmaz, S., Klotz, L.E. and Riley, D.R., 2009. A Design Process Evaluation Method for Sustainable Buildings. *Architectural Engineering and Design Management*, 5(1-2), 62-74.

Rekola, M., Makelainen, T. and Hakkinen, T., 2012. The role of design management in the sustainable building process. *Architectural Engineering and Design Management*, 8(2), 78-89.

FIRE SAFETY IN RESIDENTIAL APARTMENT BUILDINGS FOR LOW INCOME RESIDENTS IN SRI LANKA

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ABSTRACT

Fire risk is a critical matter to be considered in apartment buildings constructed for low income residents. Accordingly, management of fire safety carries a big role. However, it become a challenging task in these types of buildings due to residents' low income, educational level and social backgrounds. Hence, it is vital to evaluate the fire safety in such apartment buildings and to identify their issues. The research is focused to analyze gaps in the fire safety management. Thirty apartment buildings located in Colombo metropolis were selected for the study. Members of the management corporations were interviewed to gather data.

Finding showed that lack of knowledge and awareness, not having a proper fire safety system, lack of resources, less commitment of residents, lack of support from relevant authorities and poor maintenance practices are the most critical issues in fire safety management. Enhancing the fire regulation, increasing the awareness, implementation of proper fire safety management systems and construction technologies were identified as required improvements to fill the gap in fire safety.

Findings of the research can be considered to enhance the fire safety of apartments constructed for low income families.

Keywords: *Apartment Buildings; Fire Safety; Fire Safety Management; High-rise Buildings; Low Income Families.*

1. INTRODUCTION

1.1. BACKGROUND

Fire is high vulnerable and unpredictable disaster which consumes life and property, and thus preparation for prevention is paramount important (Waziri, 2012). Moreover, fire safety is one of the major considerable areas in high rise buildings (Chen, *et al*., 2013). Further, residential buildings have shown the highest potential to fire risk due to various household activities (Hall, 2013) and are recorded more fatalities (Stephen *et al*., 1998; Xin and Huang, 2013). Fire Service Bureau in Beijing identified that 347 civilian injuries and 853 civilian deaths from 52661 residential fire incidents (Fire Service Bureau, 2011). Further, 52,661 fires or 39.7% of all fires occurred in residential buildings in China, which results in 853 civilian deaths, 347 civilian injuries and indirect property damage of approximately 309 million were recorded in a study by Xin and Huang (2013). The USA fire department was responded to a fire every 23 seconds, one structural fire was reported every 63 seconds, one home structure fire was reported every 86 seconds, and one civilian fire injury was reported every 34 minutes (NFPA, 2015).

These fire incidents can be occurred in numerous ways. According to Waziri (2012), most of the fires are initiated as a result of household action such as, cooking, electrical system, heating equipment, smoking, candles, cloth driers, child play, lightning, kitchen equipment, fireworks and outdoor grills. Further, open flame and natural causes are contributors of the fire outbreaks (Subramaniam, 2004). According to the Palazzi, Curro and Fabiano (2015), fire can have both direct and indirect impacts on buildings and occupants. Direct damages are injuries to occupants and damages to properties. Further, Burn and suffocation can be considered as primary

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damages caused by fire and death or personal injury can be considered as serious effects (Wong *et al*., 2006). Indirect damages affect the business continuity, goodwill of the building, building operation and maintenance cost increases (Corcoran , Zahnow , & Higgs , 2016).

The last few years, residential buildings faced various types of fire accidents which caused damages to the building properties and injured residencies (Liu and Chow, 2014). To control the residential fires, mainly fire extinguishers, hose reels, fire hydrants, fire doors, etc., are recommended in the literature. The objective of fire safety systems are to prevent flashover and provide clear exit to rescue the occupants (Daniel, 2002). Further, Fitzgerald (2004) indicated, that occupants must aware the escape routes and they must be in adequate number and size to avoid blocking and queuing. Furness and Muckett (2007) indicated, when the occupancy load is high, the travel time to escape from the building depends on the flow capacity of the escape routes. Fire management is important to reduce the risk of fire deaths and injuries (Woon and Suleiman, 2015). Moreover, effective fire safety management in any facility depends on understanding of the roles and responsibilities of individuals who runs the building facility (Furness and Muckett, 2007). Fire service of Sri Lanka cannot achieve the requirement level due to many reason such as, lack of financial resources, lack of equipment and qualified fire fighters, inadequate fire safety regulation (The Sunday Times, 2016, November 13).

Fire damage in a residential apartment can be higher than in other types of buildings as occupants are unfamiliar with the use of fire safety equipment, occupants being asleep or being affected by alcohol, tenants are unfamiliar with building layout if the building has rented out for short term period and due to clothing and other ignitions materials. With a growing demand for residential apartment buildings where population density is high, concerns towards fire safety is important. However, managing fire safety in residential apartments for low income residents is at a poor level due to various limitation caused by their high population density, low income, knowledge and social background. Therefore, the research was focused to study the shortfalls in the current fire safety management in those residential apartment buildings. Two objectives were set for the research as to (a) identify the issues in fire safety management and (b) propose recommendations to overcome the issues in fire safety management.

2. LITERATURE REVIEW

2.1. FIRE SAFETY IN RESIDENTIAL APARTMENT BUILDINGS

According to Miller (2006), buildings have classified as high, normal, and low risk types of buildings in terms of fire risks. Generally residential buildings considered as high vulnerable facility for fire due to many reasons (Hassanain, 2009).

Having large quantity of combustible materials such as, mattresses, bedding and pillows, papers or magazines, clothes, upholstered furniture, boxes or bags, curtains or drapes, interior wall covering, floor covering, cabinetry, linen, and ceiling covering can increase the risk of fire (Rohr (2001). According to Waziri (2012), fire will occur as a result of an action of a domestic activity. The existence of kitchen, fuel storage, electrical equipment, and air conditioning units in residential building creates high risk of fire (Roberts and Chan, 2000). Furthermore, when occupants are asleep, there is chance for fires to grow and develop before being discovered and unconscious occupants may be less alert and also be slower to react to the situation (Stollard and Abrahams, 1999). Yang and Bin (2013) mentioned that, not having a responsible person for fire safety management, insufficient facilities with poor design especially poor investment of fire protection services, no funds for fire safety management, improper or lack fire safety systems and lack of rules and regulations are common factors in poor fire safety. Further, Furness and Muckett (2007) mentioned that panic during the fire could increase the possibility of fatalities and injuries in fire emergencies.

Fire prevention through active and passive fire protection measures can control or reduce the fire risk (Soja, 2011; Hassanain and Hafeez, 2005; Fitzgerald, 2004; Ramachandran, 1999). Features embedded in the building structure or envelop to resist the fire, occurrence of fire, smoke control and spreading the smoke throughout the building are examples for passive fire protection. Fire detection system, fire alarm system, emergency lighting, automatic sprinkler system, stand pipe and hose reel system and portable fire extinguishers are considered as active fire protection systems.

2.2. *FIRE SAFETY MANAGEMENT*

Fire safety management is the process of analyzing, evaluating, and controlling fire safety by standards, tools, policies, practices and information (Howarth and Kara, 1999). Fire safety management plays a greater role to prevent Fire disaster sand minimize fatalities and property damages (Rubaratuka, 2013; Argueta *et al*., 2009; Spadaccini, 2009). Fire safety management consists of coordination of some programs towards the prevention of devastation of fire, such as fire prevention management, fire drill and other training, maintenance of equipment, and development of emergency procedure (Nadzim and Taib, 2014).

Good fire safety management can lower the probability of fire occurrence and mitigate the consequence when a fire does occur (Sun and Luo, 2014). Fire events can be managed with proper collaboration of responsible parties including guardian, manager and fire handler and management is the major party to handle fire safety in buildings (Corcoran *et al*., 2016). Further attitudes of building owners, occupants and management staff have a greater impact in order to implement proper fire safety management (Tsui and Chow, 2004). Wang *et al*. (2011) point out that, a number of parties need to be given their contribution to achieve fire safety of the building including professional designers, fire authority and building users. Further, management policy is a significant factor in this regard (Marchant, 2000).

3. RESEARCH METHODOLOGY

Qualitative research approach was used for this study. Thirty apartment buildings for low income residents located in Colombo metropolis were selected for the study. The selected apartment buildings contain four to eight floors and the number of unit in those buildings vary from eight to two hundred and twenty two. Thirty three (33) respondents were interviewed for this research. Face to face interviews were conducted with members of the Management Corporation (MC) of those selected thirty apartment buildings. An interview guideline, which consisted with major five sections to identify issues in the fire safety management systems and probable suggestion to overcome the issues was used for data collection. Further, three experts in the apartment management field were interviewed to identify recommendations to overcome the issues in fire safety management in apartment buildings for low income people. Content analysis was used to analyze responses of interviewees using NVivo software tool.

4. ANALYSIS AND DISCUSSION

Data analysis was done using qualitative method. The findings of the interviews were analyzed using content analysis and NVivo (NUD*IST Vivo Version 11.0) was used.

4.1. *FIRE RISK*

Most of the respondents emphasized that, apartment buildings having high risk in the event of fire due to large amount of combustible materials available at residential buildings, poor condition or unsafe kitchen equipment, candles, electrical shortages, papers, and electrical equipment, children playing with matches box, lighters, and candles, lamps used for religious purposes and usage of fireworks in festival seasons. Further there were three major fire incidents identified (Table 1).

Table 1: Previous Fire Incidents

Source of Fire	**Damage**	
	Property	**Human**
Electrical shortage in an oven	Entire household was destroyed	No reported damage
Left over a switch-on iron on the table	Entire household was destroyed	No reported damage
Illegal cooking as a business using firewood	Entire household was destroyed	No reported damage

Moreover, respondents elaborated that non-availability of fire safety systems, non-compliance of regulation and illegal construction also increase risk of fire in apartment buildings. Further, low income people generally use low quality electrical equipment, aging of electrical wiring and poor maintenance of electrical system has a huge potential for a fire. One mentioned, '*extensive use of portable multi sockets has high potential for fire by overloading*'.

4.2. *FIRE SAFETY MEASURES*

Fire safety in apartment buildings constructed for low income people is at poor condition. *"There are many apartment buildings without having fire safety certificate"* revealed a respondent. It was identified that fire safety systems such as extinguishers, detectors, and sprinklers were not installed in the apartments that are constructed long years ago. Further, these fire safety systems are not installed in apartments which have been constructed recently also due to large installation cost which is in turn increased the cost of a unit. Management corporations are also not in position to invest for fire safety systems.

Moreover, passive fire safety features are not built to enhance the fire safety. Only 16 apartments have ventilated lobbies as the only fire safety feature. As a result, some of the newly constructed apartments have no fire certificates. Under these circumstances, fire safety management in apartment buildings for low income people is at a poor level. Following section discusses critical issues in fire safety management in those apartments.

4.3. *FIRE ACCESSIBILITY*

It was identified that some of the roads have been blocked by unauthorized construction and thus, the fire brigade has no access to the building in case of a fire. Placing material on the passage may cause other accidents than fire to the residents and visitors who are in the residency when fire breakout. Further, vertical accessibility through balconies also blocked by fixing of grills. It was observed that few of the buildings have fire staircase. Unfortunately, most of them can not utilized in case of an emergency as they were blocked by unauthorized construction and MCs are not in a position to take any action again those illegal activities.

One of the members in a MC mentioned "*if a fire occurs, the only solution we have is to evacuate the people to main road through main entrance of this apartment building because we do not have an assembling point within the premises.*" Further, another member mentioned that "*we can get the fire truck up to the main entrance of the apartment.*"

4.4. *FIRE SAFETY MANAGEMENT AND EMERGENCY MANAGEMENT PROCEDURES*

Results showed that there was no any standard procedures and policies regarding the fire safety management in those apartment buildings. Getting assistance from Condominium Management Authority (CMA) as the liaison party was not sought in developing such procedures.

Further, none of the building have fire evacuation procedures. Moreover, MCs have no skills or knowledge to develop such procedures. Further, members of the management corporation mentioned that *"maintaining an emergency response team is also complicated as it is difficult to find persons who can take the responsibility"*. Further, they added "*We cannot appoint an outsourcing management company including for fire safety management, as residents can't bear the cost*".

All the respondents mentioned that they were not trained or having any experience in managing fire. Thus, "*we do not know how to control residents getting panic during the event of a fire. Evacuating children and old people will be very difficult"*. All MCs are accepted to have fire drills to train residents for a fire emergency. However, incurred cost is the main issue.

4.5. *AWARENESS OF FIRE SAFETY MANAGEMENT*

The success of fire safety management heavily depends on the awareness of fire safety among the residents and their support. Most of the respondents emphasized that, the level of awareness of fire safety among the apartment residents is very low. Some residents even do not have the contact numbers of fire brigade. Most of residents in those apartments are not educated and engaged in "*street business*". Therefore, they do not have knowledge about the fire safety and no skills in operating fire safety systems (even they are installed) in an emergency. Thus, there is a huge need for training and awareness programmes.

5. Mechanisms to Improve Fire Safety

Views from experts in the field of management of apartment buildings, developers, and fire safety management were obtained to establish strategic measures in terms of system improvement, improvements in regulations, emergency preparedness and new technologies. The findings are shown in Table 2.

Table 2: Mechanisms to Improve Fire Safety

System Improvements
• Installation of fire safety systems and further their maintenance is required to be checked by the relevant authorities • Developers have to concern about fire safety and the building should be designed in appropriate manner by considering the fire safety standard • Construction of separate worshiping area for residents can be considered.
Improvements in Regulations
• National fire regulation should be implemented with the section of action taken against the non-followers of fire regulations including developers • Proper housekeeping and waste management policies are need to be developed • Amend the Apartment Ownership Law (Amendment) No.39 of 2003 with a special provision for fire safety
Emergency Preparedness
• Safety first procedure should be followed by everyone • Emergency preparedness plans and procedures should be developed. Fire department can assist MCs • As an immediate retrofit, conducting awareness programs for residents is identified. As a long solution, safety awareness can be addressed even at the school level giving knowledge on fire safety • Properly scheduled fire drills can get a good participation of the residents and it will make sure that each resident is well trained to act accordingly during a real fire breakout • Support from the Non-Governmental Organizations (NGO) can be obtained to conduct fire training programs
New technologies
• Introduce the fire trolley for residencies, since it is a package consist an axe, knife and fire extinguishers including large CO^2, dry powder, water and foam. • Apply new technologies for upcoming apartments, specially refuge floor, sky-bridge and firefighting shaft

6. Conclusions

There is the increasing trend towards the development of apartment buildings for low income people in Sri Lanka due to the scarcity of land. It is important to consider the safety needs of residents and to provide safe residential environment to all the occupants. Most importantly, fire risk has to be eliminated.

However, it was identified that apartment buildings are having high fire risks due to availability of combustible materials within confined spaces, poor condition of kitchen equipment, candles, electrical shortages, papers, and electrical equipment, children playing with matches box, lighters, and candles used for religious purposes and usage of fireworks in festival seasons. Further, heavy use of extension codes, ageing of electrical wiring and overall due to heavy use are critical fire risk causing factors.

Lack of fire safety systems, lack of awareness, lack of accessibility for fire trucks, lack of emergency management procedures, lack of knowledge and resources are inherent factors for poor fire safety management. As strategic measures to eliminate those issues, apply new technologies for upcoming apartments, introduce fire trolley for residencies, properly scheduled fire drills, Support from the Non-Governmental Organizations, amend the Apartment ownership law and fire regulation were identified. However, implementation mechanism of those strategies is needed to be sought through further studies.

7. References

Argueta, J., Mittelman, D., Salvatori, R., Brown, N., Renda, B. and Smeal, A., 2009. *An Assessment of Fire Safety in Australia‘s International Student Housing*. Qualifying Project report, Worcester Polytechnic Institute, Worcester, MA.

Chen, T., Pan, L., Zhang, H., Narayanan, S. and Soldner, N., 2013. Experimental study of evacuation from a 4-storey building. *Procedia Engineering*, 62, 538-547.

Collier, P. C., 1996. Fire in a residential building: Comparisons between experimental data and a fire zone model. *Fire Technology*, 32(3), 195-218.

Corcoran , J., Zahnow , . R. and Higgs , G., 2016. Using routine activity theory to inform a conceptual understanding of the geography of fire events. *Geoforum*, 75, 180–185.

Daniel, P. E. M., 2002. *Review of Residential Sprinkler Systems*, petterson, National Institute of Standards and Technology, NewYork

Fire Service Bureau, 2011. *China fire services: Ministry of Public Security*, International Cultural Publishing Company, Beijing.

Fitzgerald, R. W., 2004. *Building fire performance analysis*. John Wiley and Sons Ltd, England

Furness, A. and Muckett, M., 2007. *Introduction to Fire Safety Management*. Butterworth-Heinemann, Routledge, London

Hall, j., 2013. High rise building fire. 1st ed. [Online]. Available from: http://definition for high rise building. [Accessed 20 June 2016].

Hassanain, M. A., 2009. Approaches to qualitative fire safety risk assessment in hotel facilities. *Structural Survey*, 27, 287-300.

Howarth, D. J. and Kara, Z., 1999. Fire safety management at passenger terminals. *Disaster Prevention and Management*, 8, 362-369.

Liu, J. and Chow, W., 2014. Determination of Fire Load and Heat Release Rate for High-rise Residential Buildings. *Procedia Engineering*, 84, 491-497.

Marchant, E. W., 2000. Fire safety systems – interaction and integration. *Facilities*, 18(10/11/12), 444 - 455.

Miller, R., 2006. *Fire Safety Management Handbook*, Haywards Heath: Tottel Publishing.

Nadzim, N. and Taib, M., 2014. Appraisal of fire safety management systems at educational buildings. In: *Proceedings of SHS Web of Conference* (pp. 010 05 (1-7)). Penang, EDP Sciences.

National Fire Protection Association , 2015. *NFPA reports - Fires by property type, Quincy*, [Online]. Available from: http://www.nfpa.org/news-and-research/fire-statistics-and-reports/fire-statistics/fires-by-property-type. [Accessed 20 June 2016].

Palazzi, E., Curro, F. and Fabiano, B., 2015. A critical approach to safety equipment and emergency time evaluation based on actual information from the Bhopal gas tragedy. *Process Safety and Environmental Protection*, 97, 37-48.

Ramachandran, G., 1999. Fire Safety Management and Risk Assessment. *Facilities*, 17, 363-76.

Roberts, D. and Chan, D. H., 2000. Fire in hotel rooms and scenario predictions. *International Journal of Contemporary Hospitability Management*, 12(1), 37-44.

Rohr, K. D., 2001. An Update on what's burning in home fires. *Fire and Materials*, 25(2), 43-8.

Rubaratuka, I. A., 2013. Investigation of provisions of fire safety measures in buildings in Dar Es Salam. *International Journal of Engineering and Applied Sciences*, 4(4), 40-45.

Soja, E., 2011. Maintaining Passive Fire Protection System. *Build*, 124, 56-57.

Spadaccini, D., 2009. *Building fire safety*, Worksafe, Australia

Marshall, S.W., Runyan, C.W., Bangdiwala, S.I., Linzer, M.A., Sacks, J.J. and Butts, J.D., 1998. Fatal residential fires: who dies and who survives?. Jama, 279(20), 1633-1637.

Stollard, P. and Abrahams, J., 1999. *Fire from First Principle; A design guide to building fire safety*, (3rd ed.), E and FN SPON, London

Subramaniam, C., 2004. Human factors influencing fire safety measures. *Disaster Prevention and Management: An International Journal*, 13(2), 110 - 116.

Sun, X. q. and Luo, M. c., 2014. Fire Risk Assessment for Super High-rise Buildings. *Procedia Engineering* , 71, 492-502.

The Sunday Times, 2016, November 13. *Cold response to burning problem*, Colombo: The Sunday Observer.

Tsui , S. C. and Chow, W. K., 2004. Legislation aspects of fire safety management in Hong Kong. *Facilities*, 22(5/6), 149 - 164.

Wanga, Y. C., Marsdenb, J. and Kellyc, M., 2011. Challenges of Fire Fighting in Fire Engineered Built Environment. *Procedia Engineering*, 11, 583–592.

Waziri, A. G., 2012. Towards Fire Safety and Security in Grills Housing: A Review of Approach. *Interdisciplinary Journal of Contemporary Research in Business*, 4 (8), 270-288.

Wong, S. *et al*., 2006. Are our residential buildings healthy and safe? A survey in Hong Kong. *Structural Survey*, 24(1), 77-86.

Xin, J. and Huang, C., 2013. Fire risk analysis of residential buildings based on scenario clusters and its application in fire risk management. *Fire Safety Journal*, 62, 72–78.

Yang, A. Z. and Bin, L., 2013. Chinese Historic Buildings Fire Safety and Countermeasure. *Procedia Engineering*, 52, 23 – 26.

GAPS IN EXISTING APARTMENT OWNERSHIP LAW OF SRI LANKA

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ABSTRACT

The concept of condominium has gradually increased as a solution for the housing demand in Sri Lanka through the past few decades. With the development of the condominium sector Condominium Management Authority of Sri Lanka was established as the governing body of both the private and public condominiums in country. The Apartment Ownership Law (AOL) was enacted as the regulation for the condominiums by Act No 11 of 1973. The Apartment Ownership Law has amended several times up to its last amendment in 2003.

According to many writers there are many issues raised in the condominium sector and the provisions provided in the AOL are not enough to solve those issues in several situations. Furthermore, lack of research could be found about the gaps in Apartment Ownership Law of Sri Lanka. Therefore, this research study was conducted in order to find the gaps which exist in the Apartment Ownership Law of Sri Lanka.

A comprehensive literature survey was carried out to find the theoretical background and Interview survey was carried out through experienced professionals in condominium sector as well as legal sector. According to the findings of the research there are gaps in provisions relating to many areas such as compulsory registration of condominium, common properties use and enjoyment, scattered housing properties, mixed development condominiums, developers obligations and sub management corporations. Finally, suggestions were made to rectify the identified gaps in AOL.

Key words: *Apartment Ownership Law; Condominiums; Gaps; Sri Lanka.*

1. INTRODUCTION

The living condition of people affect to their health, work and lives. The condition of living and its requirements have increased during the past years. Housing facility is one of factor that affect to the living condition of the people. The housing facilities have improved to modern housing facilities from the shelter (Tao, 2015). When cities are developed, large number of population migrates to the cities for different purposes such as education, employment and better living (Perera, 1996). Colombo, the capital city of Sri Lanka has boom in the development of condominiums in past few years (Wijeyeweere, 2015). Urbanization of the cities increase the general demand for the housing (Ariyawansa and Udayanthika, 2012). The urbanisation has created the scarcity of the lands in cities and the cities are built up rapidly. As a result of urbanization, residential developments have become high rise buildings and high density residential buildings (Sirmans, Sirmans, & Turnbul, 1999).

The condominium concept was practiced in ancient Roman Empire, the citizens lived in individual houses at the center of the city and the common facilities were shared in common. This concept enabled safer and more secure environment for living (Edirimane, 2010). The word “condominium” means the joint ownership or control which is derived from the Latin (Zarin and Bujang, 1999). The Latin word “condominium” express the two characteristics of the condominium living. They are individuality and commonality. The condominium owner is entitled to the freehold title of his condominium unit as well as he enjoys the other common elements which are belong to the condominium property by sharing among other condominium unit owners also, such

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as corridors, landscaped gardens, car parks, roof, escalators, lifts and other elements that is not belong to a specific condominium unit (Edirimane, 2010).

According to Edirimane (2015), after introducing Apartment Ownership Law in 1973, it was amended a few times. Those amendments introduced provisions for the areas that had not addressed by the initial regulations. However still there are many areas which have not addressed by the Apartment Ownership Law. Further she stated that there are no regulations to address some provisions of the law that are relating to condominiums. As well as it makes difficulties to take actions by the regulator. According to many authors there are many areas that the current AOL of Sri Lanka does not address or insufficiently address. Therefore, rectifying the gaps of Apartment Ownership Law is necessary to fulfil the requirements of the necessity of condominium law. Therefore, to fulfil this requirement studies about the gaps in Apartment Ownership Law and recommendations to overcome those gaps is necessary.

2. SRI LANKAN CONDOMINIUM SECTOR

Urban livings in Sri Lanka have increased rapidly and Colombo has highest population among other urban areas of the country. The Colombo has rapid growth in housing development in past two decades as the commercial capital city of Sri Lanka. This has been undergone with both the vertical and horizontal housing because of the population growth (Senaratne, Zainudeen, & Weddikkara, 2006). The residential condominiums can be subdivided in to luxury condominiums, semi luxury condominiums and utility condominiums. The luxury condominiums have developed mainly focusing on the expatriate families and the Sri Lankan professionals who live in abroad, semi luxury condominiums for the need based market and it is popular among migrant workers. The utility condominiums are developed by the government for the benefit of government workers, low income earners and the shanty dwellers (Wijeyeweere, 2004).

2.1. APARTMENT OWNERSHIP LAW OF SRI LANKA

In Sri Lanka, the condominium Properties are regulated by the Apartment Ownership Law. The condominium Property Act No: 12 of 1970 was introduced and then thereafter Apartment Ownership Law (AOL) No: 11 of 1973 was subsequently introduced replacing the Condominium Property Act. This law is introduced for the purpose of registering the condominium properties and the transferring ownership of the developed condominium properties. Further AOL was amended several times according to the prevailing situations of those times in condominium sector of the country. Those amendments can be identified as follows,

- Apartment Ownership (Amended) Act No 45 of 1982
- Apartment Ownership (Special Provisions) Act No. 4 of 1999
- Apartment Ownership (Special Provisions) Act No 27 of 2002
- Apartment Ownership (Amended) Act No 39 of 2003

Apartment Ownership Act No: 39 of 2003 is used as the last amendment for AOL in Sri Lanka.

2.2. ISSUES IN CONDOMINIUM SECTOR

The condominium management is one of the most critical factors that should be in place in order to maintain proper condominium practices. There are many issues that are relating to the condominiums such as maintenance issues, developers issues, unauthorized construction, non-registrations and disputes of neighbors. According to the Central Bank of Sri Lanka (2007) poor maintenance that were carried out for the urban housing schemes have become a burden to the government. There are increasing number of condominiums that are constructed in Sri Lanka as a result of increasing demand in the housing market. These constructions are going to be affected for maintenance problems in the condominiums which can be occur as a result of the faults in design, construction and building maintenance practices.

According to De Alwis (2010) there are some developers who delay the setting up of the management corporation of condominium unit owners. Within this period there is no proper audit accounts and also the collecting of management fees from the unit owners. Further he stated that there are disputes between developers and Management Corporations mostly present in several areas. The other issues is the unauthorized constructions in condominium facilities. These constructions can occur in many ways such as encroaching common areas such as open spaces in ground and public circulation places and replacing existing elements ignoring the aesthetic appearance (Mirihagalle, 2008). These unauthorized constructions have been a burden for governing proper condominium properties. As a result of these constructions government faced many difficulties when carry out maintenance for the common elements in government condominiums (Naalir, 2010).

Therefore, it is vital to consider whether the provisions of law is sufficient to address the issues arise in condominiums. There are several kinds of issues that necessitates the proper management of condominiums in Sri Lanka and they can be categorized as the problems that are encountered by unit owners or problems relating to the owners, issues relating to facilities management and issues relating to the developers.

3. RESEARCH METHODOLOGY

A background study was carried out to identify the research problem and aim and objectives were established to identify the Sri Lankan condominium sector and gaps in apartment ownership law. Under the qualitative research approach, this study was conducted through a semi structured interview survey with the individuals whom related to condominium sector. These interviews were carry out with a sample of respondents that have been selected in order to collect data. The sample of respondents were selected by using Snow Ball sampling method and interviewers were selected from Government Authority Representatives, Lawyers, Condominium Managers and Condominium Developers.

4. CURRENT PRACTICE OF SRI LANKAN CONDOMINIUM SECTOR

The Sri Lankan condominium sector had a rapid development in recent years. The condominiums that exists in the industry can be divided into two categories according to their developer. The first one is private sector which have developed condominiums by non-government organizations comes under this sector.

The other one is public sector which have developed condominiums by the government, comes under this category. Apart from this classification there are three main condominium types that have identified by the respondents. They can identify as High Luxury Condominiums, Middle Income Condominiums and Low Income Condominiums. This classification mainly focused on the facilities provided by those condominiums.

From Colombo to beginning of the Gampaha area is identified as most suitable area for development of condominiums and with the upcoming condominiums in Colombo there are nearly 8000 luxury apartment units in the Colombo area. With this increasing luxury apartment units supply, They should be attract the foreigners to invest in these properties in order to minimize the negative effects that can have by oversupply of the condominiums. The most of the upcoming developments are mixed development condominiums in the country. When consider about the middle income and lower income condominiums government involve to developing them and government placed more concern on lower income condominiums than middle income condominiums. There are many private sector developers who are engaged with the middle income condominium property development. There are many issues faced by the condominium sector currently in Sri Lanka. Unauthorized constructions are major issue that most of government as well as private condominiums have faced.

These unauthorized constructions are a threat to building appearance and also to the safety of the occupants. When concern about the others issues, the number of issues and nature of the issues have been changed through time to time. When it comes to present situation these issues have changed more when compared with the past. One of the issue that is mainly faced in the condominium sector is neighbours’ disputes. There are several kind of disputes that are raised by the neighbours. There are maintenance problems in the low-income condominium facilities due to the lack of support of the community for the maintenance activities and most of the low income condominiums does not have active management corporations to manage the condominium property. There are issues relating to the common elements uses such as parking facilities. There are many condominiums which have not proper parking facilities for the unit owners. When there is inadequate parking facilities disputes are raised within the unit owners.

When consider about the practice of the apartment ownership law, 76.90% of respondents stated that the apartment ownership law is not practiced properly and 15.40% stated that the law is in ordinary practiced. The rest of 7.70% said that the law is practiced properly. However, all sated that the Apartment Ownership Law should be amended to fulfill the current requirements in the industry.

5. IDENTIFIED GAPS AND SUGGESTIONS TO IMPROVE THE AOL

5.1. COMPULSORY REGISTRATION OF CONDOMINIUMS UNDER AOL

In Sri Lankan apartment ownership law, there are many areas that should amended to fulfill the current requirements in the industry. Several areas that should be included in the apartment ownership act necessarily in order to maintain proper condominium sector have been identified. The respondents have mentioned that thus Apartment Ownership Law made provisions to register the condominiums. It does not mention that the registration of the condominium is compulsory. Therefore, non-registration of condominiums caused many problems when involving the authority for their disputes. Therefore, compulsory registration is necessary to include in AOL.

5.2. PROVISIONS FOR MIXED DEVELOPMENT CONDOMINIUMS

There are many mixed developments which are upcoming in the industry. There are few luxury mixed development condominiums in Colombo and in time to come there will be more mixed development condominium properties within the Colombo with current development of the country. Mixed development can be identified as condominiums which are used for both the residential and commercial purpose. Hence this kind of building consists with different kind of spaces in same premises, there should be proper governing rules for these properties. When consider about the purpose of using the spaces there is uncertainty that these premises can use one law or there needs to be separate laws for each kind of space.

Therefore, mixed development condominiums should have proper governing rules. These mixed developments come under the condominium concept though there are no special provisions relating to the mixed development condominiums in Apartment Ownership Law. When consider about the current development of these condominium properties it is necessary to have such provisions relating to the mixed development condominiums to ensure proper practices and legal background for those condominiums. Therefore, having provisions for mixed development condominiums in the AOL is necessary.

5.3. PROVISIONS FOR SUB MANAGEMENT CORPORATIONS

The mixed developments are complex developments and there should be an effective management corporation to manage the property. Mixed development condominium management is critical due to their complexity. Therefore proper managing practices should be in place. The Management Corporation of the condominium is liable for getting decisions relating to the management of the property. Therefore, Management Corporation should have established in a manner that the corporation can perform more effectively and efficiently. There are many countries which have introduced new concepts and features to the Management Corporations of the condominiums. These concepts were introduced in order to obtain effectiveness of the Management Corporations and on the other hand they have introduced to deal with specific interests which are relating to the mega condominium buildings.

On the purpose of that multi-tiered management corporation can be used. The management corporations which have subsidiary management corporations within the main management corporation for legal and operational aspects separately is ideal for the mixed development. All the subsidiary management corporations operate under the supervision of the main management corporation. Therefore, main management corporation will remain the overall charge of the condominium. This kind of management corporation structure is necessary for the mix development condominium and current AOL does not consist with such provisions. Therefore, it is necessary to have such provisions in the AOL.

5.4. PROVISIONS FOR SCATTERED HOUSING PROPERTIES

The scattered housing or cluster housing is housing concept that is existing in Sri Lankan housing market. These houses or properties share the common facilities of the properties. They can be identified as swimming pools, gardens, clubhouse, car parks and community halls. The facilities are used in common by all the house owners and as a result of that house owners have rights on the common facilities in the premises. Though they use common facilities in common, the housing units may be detached from each or semi-detached. Therefore, the housing units and common facilities are scattered within one area. These kinds of developments do not come under the concept of condominium. These housing should have a governing body to govern the common properties. There is no such governing body, in that circumstance common facilities can be governed by the AOL. Therefore, these types of houses should be come under the AOL to have proper management of their common properties. Therefore, provisions for scattered housing should be necessarily include in the law.

5.5. PROVISIONS FOR COLLECTING MANAGEMENT FUND BASED ON USE OF COMMON PROPERTIES

The management corporation collects funds from unit owners to maintain the condominium property. In many situations, the same amount or an amount based on the share value of the unit, funds have been collected from the unit owners for management fund. There is right to use the common properties equally for the unit owners of the condominium. The usage of common properties may differ from the unit owners to another. In such cases, there should be a formula to calculate the amount of contribution for the management fund rather than calculating it according to the share value of the unit. On that perspective, the apartment ownership law should provide necessary provisions to adopt this method for Sri Lankan condominiums. Therefore, the apartment ownership act can be introduced a flexible formula for the contribution of management fund of the condominium property.

5.6. PROVISIONS FOR PROPER TENANCY PRACTICES IN CONDOMINIUMS

Another area which the law provisions does not exists is the tenancy of the condominium units. In many situations condominium buyer tends to buy condominiums as an investment method. The buyers who had bought the condominium units as investment, rented them to another party in many occasions for certain time period which can be a shorter period or longer period. In such situations, the management of the condominium property faced several issues relating to these tenancy. The management corporation may not aware of the tenancy of particular tenant and the owner of the unit also may not take actions to inform about the tenancy to the management. It will raise issues such as tenants may not be aware of the regulations of the condominium, such as how to react in emergency and other practices of the condominium. Therefore, the tenancy which is not formed in proper manner may become burden for the management of the condominium. Therefore, sufficient provisions relating to the tenancy of the condominium units should be included in the law to have proper condominium industry.

5.7. PROVISIONS RELATING TO DEVELOPERS OF CONDOMINIUMS

Condominium developers are also important for the development of the industry as well as owners. The AOL included provisions relating to the owners only. It does not included provisions relating to developers. Therefore, it is important to include provisions which makes developers more liable for their activities.

5.8. PROVISIONS RELATING TO COMMON PROPERTIES USE AND ENJOYMENT, PROPER PARKING FACILITIES AND OTHER AREAS

The law consists with provisions not to interfere with another owner’s common element usage or enjoyment but the AOL does not consists specific provisions regarding the usage and enjoyment of common properties. Moreover, there was not clearly mentioned provisions relating to the parking facilities of a condominium and there are areas which does not clearly or sufficiently addressed by Sri Lankan AOL such as building appearance and keeping pets in the condominium units. Therefore, these kinds of areas should be included in the law to have a proper condominium industry.

6. CONCLUSIONS

The condominium industry of Sri Lanka has been developed rapidly for the past few decades and in present it has become more rapidly developed. Both private and the public sectors are actively involved with the development of condominium properties in the country. The demand for the condominiums has increased as well as the supply have gone up. There are issues relating to condominiums including maintenance issues, developers' issues, unauthorized construction, non-registrations and disputes of neighbours. As a major industry it is necessary to have proper governing rules and regulations for betterment of the industry. The Sri Lankan condominium sector is govern by Apartment Ownership Law which was enacted in 1973.The Apartment Ownership Law was enacted to govern the condominiums in the country and it was amended few times according to the requirement of the industry. Though there were amendments to the AOL with the rapid development of the industry it is necessary to update the AOL incorporating with the new requirement of the industry.

In order to identify those requirements, it is necessary to identify gaps exist in Apartment Ownership Law. There are several areas that should improve in the AOL including compulsory registration of condominiums under AOL, provisions for mixed development condominiums, provisions for sub management corporations, provisions for scattered housing properties, provisions for collecting management fund based on use of common properties, provisions for proper tenancy practices in condominiums, provisions relating to developers of condominiums, provisions relating to common properties use and enjoyment, provision for proper parking facilities, provisions relating to other areas. Therefore, the AOL should be amended to rectify the identified and this study may support to provide knowledge about suggestions to update AOL in Sri Lanka.

7. REFERENCES

Ariyawansa, R. G. and Udayanthika, A. G., 2012. Living in high-rise: An analysis of demand for condominium properties in Colombo. *International Journal of Sociology and Anthropology*, 4(1). 31-37

Central Bank of Sri Lanka, 2007. *Annual Report of Central Bank of Sri Lanka*, Colombo: s.n.

De Alwis, K. A., 2010. *How high-rise apartment owners are taken for a ride tricks developers play*. The Island, 14 June.

Edirimane, A., 2010. Understanding the concept of condomoniums. 3rd ed. Ceylon Printers Ltd: Colombo.

Edirimane, A., 2015. *What ails the condominium industry in Sri Lanka*. The Sunday TImes, 08 March.

Mirihagalle, L., 2008. *Unauthorized alterations in condominium housing in Sri Lanka*, s.l.: s.n.

Naalir, M., 2010. *Facelift for NHDA apartments*. Sunday Observer, 21 March.

Perera, A. L., 1996. *Some Land Planning and Land Development Issues in Sri Lanka*. 1st ed. s.l.:Perera, A. L. (1996). Some Land Planning and Land Development Department of Town and Country Planning, University of Moratuwa.

Senaratne, S., Zainudeen, N. and Weddikkara, C., 2006. Factors affecting condominium development in Sri Lanka. *Built Environment Sri Lanka*, 7(1). 23-28

Sirmans, G. S., Sirmans, C. F. and Turnbul, G. K., 1999. Prices, incentives and choice of management form. *Regional Science and Urban Economics*, 29(2). 173-195

Tao, L.W., 2015. Living conditions—The key issue of housing development in Beijing Fengtai District. *HBRC Journal*, 11(1), pp.136-142.

Wijeyeweere, C. A., 2004. *Condominium development, management and the condominium law*. Daily News, 31 August.

Wijeyeweere, C. A., 2015. *Condominium development management and the condominium law*. Condominium News Bulleting Magazine. 31 August 2004

Zarin, H. A. and Bujang, A. A., 1999. *Factors influencing demand for condominium in Johor Bahru*, Malaysia.. Kuala Lumpur.

HYBRID RENEWABLE ENERGY AS A SOLUTION FOR THE ENERGY CRISIS IN SRI LANKA

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ABSTRACT

The global energy industry is at the edge of fundamental revolution where renewable energy plays a major role in responding to the challenges ranging from sustainability to environmental protection. However, the use of a single renewable energy source in producing energy has been reducing due to the inconsistency of resource streams. Consequently, the enhanced energy management strategies were developed by integrating renewable resources with a standby entity and hence hybrid renewable energy systems explored to the practice. Producing energy to unlimited increasing demand is a challenging issue currently faced by Sri Lanka. Although some studies have been performed for hybrid renewable energy systems, i.e. wind and solar across the world, this is an understudied area and thus, very little information is available in Sri Lanka. Therefore, the purpose of this paper is to examine the applicability of solar and wind hybrid renewable concept as a solution for energy crisis in Sri Lanka. A comprehensive literature review was conducted to identify the significance and the emergence of hybrid energy sources. Eight (08) semi structured expert interviews were conducted with information related to solar, wind, renewable energy sources, and hybrid systems, by adopting a qualitative research approach. Collected data were then subjected to content analysis in deriving the research outcome. The findings revealed positive perceptions on implementation of solar–wind hybrid renewable energy systems in Sri Lanka and the importance of intervention at policy level for the success. Lack of knowledge on hybrid concept and updated technologies, limited financial investments, and policy incentive dilemmas, were identified as few limitations.

Keywords: *Hybrid Energy System; Renewable Energy; Solar Energy; Wind Energy.*

1. INTRODUCTION

Global electricity trend has accelerated by 250% with the world's population growth over the past 40 years; further it is forecasted a growth of 70% in 2030 with regards to current energy consumption pattern (International Renewable Energy Agency [IRENA], 2014). The energy demand has substantially increased due to recent industrialization, urbanization, and population growth in South Asia. The import reliance for energy needs has raised from 10.43% in 1971 to 24.76% in 2010 of total energy demand, seriously questioning the sustainability of the current energy mix and energy security (Vidyarthi, 2014). The situation has become much more critical in case of countries such as Sri Lanka, Bangladesh, Pakistan, and Nepal (World Bank, 2013).

Rapidly growing world energy consumption has already impacted on sustainability issues, heavy environmental impacts such as ozone layer depletion and global warming, and exhaustion of energy sources and supply difficulties (Perez-Lombard, Ortiz, and Pout, 2008). A significant role will have to be played by renewable energy sources, in moving the world towards more safeguarded, sustainable, and reliable energy gateway in line with these issues (World Energy Outlook, 2015). Renewable energy currently contributes to around 13% of total global primary energy supply and 11% of total energy supply in European Union, whereas the percentage is growing progressively (Johansson, 2013). Concurrently, in developing countries, among the energy policy targets, utilizing renewable is becoming noticeable as a regulatory interference for the promotion of renewable based clean energy generation (Wijayatunga and Prasad, 2009).

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Sri Lanka has a long history of using renewable energy, dating back to early 20th century, when most tea plantation companies installed small hydropower plants for their power generation (Wijayatunga, 2014). According to Generation and Reservoir Statistics (2017), total primary energy requirement of the country has been met with Thermal (31%), Thermal oil (28%), Coal (20%), Hydro (17%), followed by Wind (3%) and Solar (1%). Even though the current government policies have given a target of 20% renewable energy by 2020, it is the economic and practical realities that hold back the development of renewable energy sector (Withanaarachchi, Nanayakkara, and Pushpakumara, 2015).

Subsequently, Hybrid energy systems are becoming energy systems of choice for future energy deficit issues (Perera, Attalage, Dassanayake, and Perera, 2013). Hybrid renewable energy systems (HRES) thatconsist of solar, wind, biomass, and other energy generation and storage units, have been widely studied in recent years. Many studies have reported on modelling, and control and optimization of hybrid energy systems from design to operation (Wang, Palazoglu, and El-Farra, 2015). A combination of resources with a back-up unit, or a hybrid system, is economical, and possibly will increase system sustainability and depress energy production costs (Rahman, Khan, Ullah, Zhang, and Kumar, 2016).The latest status of hybrid renewable energy system (HRES) technological advancement is the outcome of accomplishments in many research fields that have expressed at tremendous potential in precisely predicting the reliability of integrating solar, wind, and other renewables (Nema, Nema, and Rangnekar, 2008). As many countries are now on the verge of moving towards implementing hybrid renewable energy systems, Sri Lanka has also taken an important decision with integrating HRES. Hence, this paper examines the applicability of hybrid renewable energy concept as a sustainable energy solution to the expected future energy deficit in Sri Lanka. The paper structure begins with an introduction to the study followed by a literature review on world energy challenge, significant role of renewable energy, growth of solar and wind energy, and the emergence of HRES in section 2. Section 3 presents the research methodology whereas section 4 presents the suitability of solar and wind sources as a hybrid energy solution in Sri Lankan context with strategies for the successful implementation of a solar wind hybrid system. The final section summarises conclusions derived from the research findings and recommendations.

2. Literature Review

2.1. Introduction to World Energy Challenge

World energy is at the heart of transformation at present, together with the aim of intensifying energy security and leading to a sustainable future (International Renewable Energy Agency, 2014). The world's population is increasing daily, which is predicted to reach 9.6 billion by 2050 (Pathak, 2014).

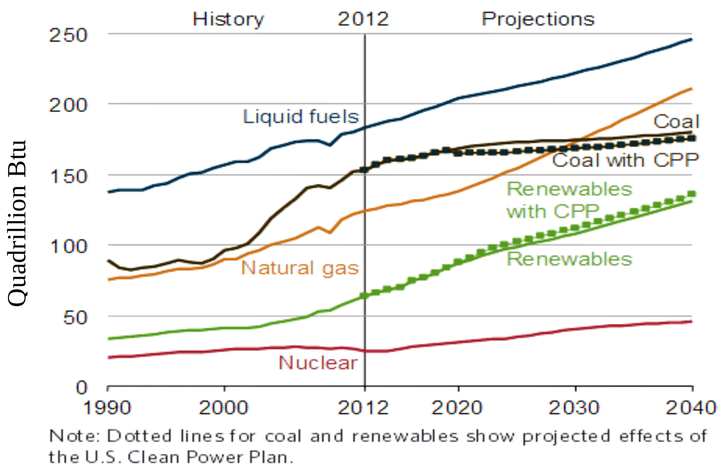


Figure 1: Total World Energy Consumption by Energy Source from 1990 to 2040

Source: World Energy Outlook (2010)

The immense growth of economy during the past decades, particularly the emerging economies, has encouraged world energy consumption significantly, putting an exceptional pressure on succeeding energy-saving (Huang, 2014). Owing to the crucial role of energy in everyday life and multi-dimensional strategic importance of sectors, the multi-aspect, regularly international, spatially differentiated, and dynamic nature of energy sector issues, are concerned (Bhattacharyya, 2007).Moreover, highlights of World Energy Outlook (2010) regarding the total world energy consumption by energy source predicted up to year 2040 with regards to past few decades, is presented in Figure 1.

As depicted in Figure 1, world energy consumption is rising gradually and the dotted lines show projected effects on the future energy consumption of renewable. Global energy crisis also raise uncertainties on recovering and remaining amounts of non-renewable resources such as coal, natural gas, and oil, due to the fact that new resources are not being created because currently the world possess only those created million years ago (Pathak, 2014). Eventually, the world would run out of these resources whereas reserved oil, gas, and coal, is expected to last for 35, 37, and 107 years respectively, during which, coal happens to be the isolated fossil fuel remain after 2042 (Shafiee and Topal, 2009).

2.2. SIGNIFICANT ROLE OF RENEWABLE ENERGY

Global fuel crises, over dependency on fossil fuels, greenhouse gases (GHGs), climate change, and global warming, are the significant challenges of energy sector that was strengthened with the extraordinary energy demand owing to the population growth (Mohanty, 2012). The remarkable rapid expansion of energy consumption in the past several decades has extended alarms on exhausting petroleum and other global reserves in the near future, guiding the economy and technologies to largely rely on non-replaceable natural resources (Alrikabi, 2014). Successively, the global ambition on green economy was materialized, which boosts a country’s economy while promising a sustainable environment (Pan, Ma, and Zhang, 2011) during which the requirement for energy efficiency solutions has directed to a significant interest in renewable energy sources (Henriques, Hedges, Owen, and Poole, 2016).

Renewable energy sources have become the world’s fastest emerging energy source over the last few decades while the consumption of renewable energy is increased by an average of 2.6% between years 2012 to 2014; this would be 4 quadrillion Btu by 2040 (International Energy Outlook, 2016). The term “renewable energy” has derived from a broad diversity of resources, generally based on self-renewing energy sources such as sunlight, wind, water falling, internal heat of earth, and biomass such as energy crops, industrial, agricultural waste, and municipal waste (Bull, 2001).

2.3. GROWTH OF SOLAR AND WIND ENERGY

Solar and Wind technologies are economically worthwhile in the present day in an increasing number of markets, which further make important stages to enlarge commercialization, since they are abundant intercontinentally (Bull, 2001). For both solar and wind systems, not only the fuel cost is constant but also it is zero throughout the system’s life (Bull, 2001) and enormous investments are anticipated during the next 15 years for both sectors (Ying, 2007). It is predicted that wind and solar accounts for more than 10 percent of world electricity production in 2040, up from 4 percent in 2014. The biggest volume growth will come from wind, which by 2040, is anticipated to supply about 2 percent of global energy and nearly 10 percent of its electricity (The Outlook for Energy: A View to 2040, 2016).

Solar energy resources maps developed by Sri Lanka Sustainable Energy Authority (SLSEA) represent the distribution of solar energy potential throughout Sri Lanka in four different aspects. Those are the annual global horizontal irradiation (GHI), annual direct normal horizontal irradiation (DNI), Energy optimizing mounting angles (PV panels), and annual PV electric potential (kWh/kWp) for different regions. The highest potential areas can be identified as Puttlam, Mannar, Kilinochchi, Jaffna, Hambantota, and the coastal areas. Wind energy resources maps developed by SLSEA represents the distribution of wind energy potential throughout Sri Lanka in annual average wind speed aspect. Mannar, Jaffna, Puttlam, and Punarine, have been identified as the best potential areas.

Generation of electricity through renewable energy sources has become a major concern in Sri Lanka with the prediction of present electricity consumption level of 3,950 MW being increased at a rate of 7% annually, which spotlighted the need to generate an additional 3,000 MW capacity by the year 2025 (Ministry of Power and Energy, 2015). Further, Energy development plan for 2015-2025 (2015) states that a considerable amount from 3000MW new requirement is planned to be generated through renewable energy sources that includes building of wind power plants of 600 MW and solar power plants of 3,000 MW in the next ten years. The current solar and wind installations in Sri Lanka totals up to a capacity of approximately 33MW produced through 6500 solar installations and around 129MW generated through the wind turbines by 2016 (Sri Lanka Sustainable Energy Authority, 2016).

2.4. EMERGENCE OF HYBRID RENEWABLE ENERGY SOURCES (HRES)

The distribution of renewable resources is boundless, yet the use of a single source to produce energy is not reliable ever since the resource stream is not constant (Rahman, Khan, Ullah, Zhang and Kumar, 2016). The regular drawback to wind and solar energy alternatives are their unpredictable nature and their reliance on the environment and climate changes (Pradeepkumar, Azhagiri, Senthilkumar, and Kumaragurubaran, 2016). Consequently, enhanced energy management strategies are recommended (Dursun and Kilic, 2011), whereas integrating of resources with a standby entity, or a hybrid renewable energy system, assists in addressing this matter of unreliability (Dagdougui, Minciardi, Ouammia, Robbaa, and Sacile, 2012). Furthermore, Pradeepkumar *et al.* (2016) stated that a continuous power production will possibly be anticipated with a hybrid power system by combination of two or more resources, utilizing the potentials of one resource to rise above the limitations of the other source.

Hybrid energy systems are becoming energy systems of choice for future energy deficit issue (Perera, Attalage, Dassanayake, and Perera, 2013) that consist of solar, wind, and other energy generation and storage units, which have been widely studied in recent years. A combination of resources with a back-up unit or a hybrid system is economical and possibly will increase system sustainability and depress energy production costs (Rahman, Khan, Ullah, Zhang, and Kumar, 2016). As per the findings of Atwa, Saadany, Salama, and Seethapathy (2010), probabilistic-based planning techniques are proposed for determining the optimal fuel mix of different types of renewable Distributed Generation (DG) units to minimise the energy loss per annum in the distribution system without disrupting the system constraints.

Moreover, Rezaie, Esmailzadeh, and Dincer (2011) determined that the hybrid technique can grant higher efficiency, lower energy costs, and progress sustainability, through lower emissions, and concluded that it is more desirable than standalone systems with relate to the above cited three indicators. Similarly, Ehyaei, Ahmadi, Atabi, Heibati, and Khorshidvd (2012) concentrated on three perspectives; economic, energy, and emissions, for investigating an onsite hybrid system outfitted in a residential building, and ascertained that a hybrid system can accomplish a first class performance.

2.5. OPTIMAL ENERGY COMBINATION FOR A HYBRID RENEWABLE ENERGY SYSTEM

Ascertaining optimum system combination is an important fact at the premature design stages of Hybrid Energy Systems (Gupta, Saini, and Sharma, 2011). Having considered the complications of fluctuating project sites and intended functions, determining the optimal renewable energy combination for a specific site can be identified as a challenging process. Numerous investigations have been worked out to achieve the best energy fusion of a hybrid energy system and the combination relyon the accessible renewable energy resources and the load demand of the specific site (Rahman, Khan, Ullah, Zhang, and Kumar, 2016). Moreover, conflicting dynamics such as cost, greenhouse gas emission, operation efficiency of renewable energy, and unmet load fraction are considered to achieve multi objective optimization (Agustín, López, and Ascaso, 2006; Agustín and López, 2009). Fadaee and Radzi (as cited in Perera, Attalage, Perera, and Dassanayake, 2013) reported that it is important to adjust to the multi objective optimisation process to match a particular hybrid energy system with the local environment.

As per the findings of Yang, Wei and Chengzhi (2009), an optimum sizing method is necessary to guarantee the most efficient, reliable, and economized techno-economically optimum mix of renewable energy sources. Several sizing algorithms are available based on probabilistic approach, graphical construction method, iterative approach, artificial intelligence method (Wei, Chengzhi, Zhongshi, Lin, and Hongxing, 2009), numerical approach (Kellogg, Nehrir, Venkataramanan, and Gerez, 1996; Kaabeche, Belhamel, and Ibtiouen, 2011), and heuristic techniques (Hochmuth, 1997) have been recommended to develop the optimum combination.

3. RESEARCH METHODOLOGY

The plan of the research, which is used to move from the research question to the conclusion, is defined as research design (Tan, 2002). As per the view of Yin (2011), the research design can be performed either at commencing or during progressing, since research design can be changed during the cause of study. The design of this research includes literature survey, expert opinion survey, data analysis, and the discussion of research findings, respectively.

In-depth expert opinion survey was used for the study since the research topic was associated with detailed data requirement. On the other hand, the experts available with the specific knowledge related to hybrid renewable energy systems were very less within the industry. Hence, obtainable sample size was less. Therefore, the research was conducted under the qualitative approach by considering its advantage over the quantitative approach. Further, the information gathered were mostly the opinions of the interview participants and needed to be evaluated in a descriptive way. Hence, the research compelled the qualitative research approach.

Hence, eight (08) experts were interviewed using semi-structured interview guideline as the major data collection technique. The interviews were conducted among industry experts in the fields of solar, wind, and hybrid renewable energy systems (refer Table 1). Content analysis, which is a qualitative data analysis technique, analyzed the collected data by considering its merits over other techniques. Among the several data analysis softwaresto support the content analysis, this study selected NVivo (2011), which contained graphical presentation of interpreting relationships.

Table 1: Profile of Interview Participants (IP)

IP	Discipline	Experience (Years)	Field of expertise	Awareness of the hybrid concept
IP1	Former Director/Senior Lecturer	35	Expert in the field of solar, wind, biomass, and hybrid	Well aware
IP2	Director General	20	Expert in the field of solar, wind, and hybrid	Well aware
IP3	Managing Director/ Visiting Lecturer	30	Expert in the field of solar, wind, and hybrid	Well aware
IP4	Training Engineer	15	Expert in the field of solar and wind	Well aware
IP5	Senior Lecturer/ Consultant	16	Expert in the field of sustainable design and construction	Aware
IP6	Senior Lecturer/ Consultant	15	Expert in the field of solar	Aware
IP7	Senior Lecturer/ Consultant	16	Expert in the field of solar	Aware
IP8	Senior Lecturer/ Consultant	15	Expert in the field of high voltage engineering, electric power, and wind	Aware

4. RESEARCH FINDINGS AND DISCUSSION

4.1. SOLAR AND WIND ENERGY IN SRI LANKA: INSTALLATION AND CURRENT PRACTICE

This section presents research findings of factors considered during the installation and current practice of solar and wind, based on experts' opinions.

As revealed during interviews, the location and solar irradiation, shading, technology used, angle of installation, maintenance of the solar panel, cooling technique for the panel, tracking method, quality of electronic components, intermittency and fluctuation, reactive power, storage, area available for the installation, orientation of the roof, investment, and the return on investment were identified by the experts as important factors to be considered during the installation of solar panels. Figure 2 illustrates each factor with number of responses.

The experts reported that Jaffna, Mannar, Hambantota, and Puttlam areas have the highest irradiation levels, which further reinforce literature findings. All interview participants believed that panel location is affected by the shading from buildings, trees, or clouds, which disturb the sunlight entrance where system requirement was not achieved. The norm is that country of origin basically impacts the technology where German technology is preferred more in installations.

Nodes

Name	Sources	References
Factors considered when installing solar PV	7	39
Location and solar irradiation	5	9
Angle of installation	3	3
Tracking method	1	1
Technnology	4	5
Quality of electronic components	2	2
Shading	3	3
Maintenance of the panel	3	3
Cooling technique for the panel	3	3
Intermittency and fluctuation	1	1
Reactive power	1	1
Storage	1	1
Area available for the installation	1	1
Investment	2	3
Return on investment	1	1
Orientation of the roof	1	1

Figure 2: Factors Considered During Installing Solar Panels

IP1 stated that angle of installation is not sharp 90^{o} and depends on direct radiation and diffused radiation. The suitable angle can be decided through SLSEA solar maps. Solar panel efficiency drops without periodical cleaning during proper intervals [IP1, IP4, and IP7]. The findings revealed that operating temperature of the panel highly influence the efficiency. Supporting to this fact, IP1 stated,

> "*Ambient temperature is usually higher in Sri Lanka. Central province has better efficiency due to lower temperature. Although the outer environment temperature is 30^{o}C, the panel temperature is about 50-60^{o}C, which is less efficient. Usually, Hambantota solar panels have an increased temperature of 70^{o}C.*
>
> *Therefore, cooling technique for the panel is an important fact. This may be natural cooling through rain and wind. But if it's artificial cooling, it will not be cost effective. It will be easy to make the environment cool through growing grass instead of having pebble roads but that will also incur a maintenance cost.*"

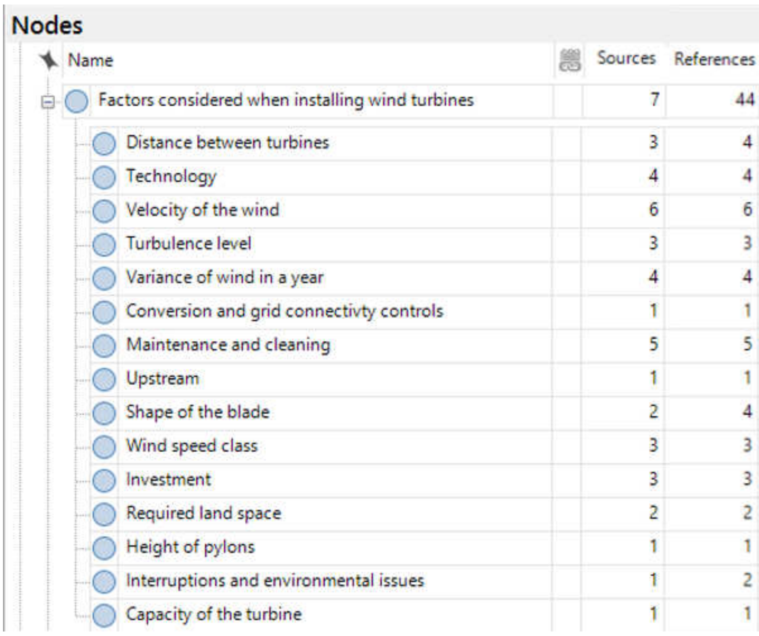
As revealed by IP1, if these factors act negatively, the average solar panel efficiency of 17% can reduce. Although it cannot be exactly determined, there are norms that can be related with efficiency and can quantify the efficiency drop. Only about 10-15% of the average 17% efficiency can be varied through these factors, but not by a bigger percentage such as 50%-60%. All experts agreed that Roof top solar panels were the most popular installation in Sri Lanka. It revealed three schemes, which are currently used in connecting the solar panels; net metering, net accounting, and net plus schemes.

Similarly, Figure 3 illustrates the factors to be considered during the installation of wind turbines: Wind velocity, wind speed class, distance between the turbines, maintenance and cleaning, shape of the blade, technology used, turbulence level, variance of the wind in a year, conversion and grid connectivity controls, upstream, investment, required land space, height of pylons, interruptions and environmental issues, and capacity of the turbines as have identified by the experts.

The findings revealed that the annual average wind speed also can be identified through the resource maps developed by SLSEA. Wind speed class in the site relates to the wind velocity. IP1 mentioned that,

> "*... usually class 7 is the best whereas at a height of 50m, a7-8m/s average velocity is present. Mannar and Jaffna are in class 7 range and Hambantota in class 5-6 range. The class is decided by the energy*

availability in kWh per m^2. How much energy can be generated for 1 m^2 is reflected in this class. This can be converted to velocity or to energy. Usually class 4-5 is the minimum requirement and 6-7 is the best."



Nodes

Name	Sources	References
Factors considered when installing wind turbines	7	44
Distance between turbines	3	4
Technology	4	4
Velocity of the wind	6	6
Turbulence level	3	3
Variance of wind in a year	4	4
Conversion and grid connectivty controls	1	1
Maintenance and cleaning	5	5
Upstream	1	1
Shape of the blade	2	4
Wind speed class	3	3
Investment	3	3
Required land space	2	2
Height of pylons	1	1
Interruptions and environmental issues	1	2
Capacity of the turbine	1	1

Figure 3: Factors Considered during Installing Wind Turbines

The norm for the distance between the turbines is to have a distance of 5-6 times a diameter of the blade. For example, if the diameter is 100m, the distance between two hoods should be at least 500m. From behind, it should be 8-9 times diameter distance. Dust on blade surfaces should be cleaned to gain the best energy production though wind turbines [IP1, IP3, IP4, and IP8].

The interview participants reported that Pitch controlling changes the angle of blade according to the wind direction. Stall controlling is simpler than pitch controlling where the blade from its shape changes its performance according to the velocity.

The shape of the blades are called *aero foil shape*. The profile of the blade is changing daily and blade material developments such as carbon fiber with low weight are invented [IP1].

IP1, IP2, IP5, and IP7 mentioned that three (03) bladed horizontal axis wind turbines is the most popular and matured technology, where two (02) blades has a balancing issue. There are improvements in blade profiles.The two connectivity practices which are currently used in installing wind turbines in Sri Lanka were *grid connected* and *off grid installations*.

Moreover, the study identified competencies and confines related with solar and wind energy at two different stages named during installation and during operation. Table 2 reports the summary of experts opinions received during the interviews.

Table 2: Competencies and Confines of Solar Panels and Wind Turbines in Sri Lankan Context

	Solar	**Wind**
Competencies during installation	– Technology development – Increased cell efficiency – Good solar potential – Availability of solar maps – Supportive government policies – Higher number of suppliers – Availability of loans	– Availability of wind resource maps – Abundant wind supply – Supportive government contribution
During operation	– Specialization savings – Lesser maintenance	– Technology and knowledge flow – Technology inventions

	Solar	Wind
	– Availability of norms on modelling	
Confines During installation	– Technological barriers – Less investments – Higher initial cost – Damages through lightning – Longer pay back periods – Limitations through guidelines	– Limited number of experts – Undeveloped infrastructure – Difficulty in handling higher capacity turbines – Higher initial cost – Unavailability of bankable data – Larger area for the installation
During operation	– Limited number of experts – No local manufacturing	– Turbulence effect – No proper modelling and controlling – Less local manufacturing

4.2. *GROWTH OF SOLAR AND WIND ENERGY IN SRI LANKA*

As found from the participants, over 500 suppliers are available in the market for solar installations while more than 50 of them are registered at SLSEA. Nearly 83762 households have been provided electricity through solar panels of 10-15kW under Rural Electrification and Renewable Energy Development (RERED) project. It was found that solar energy currently contribute to about 12% of energy generation in Sri Lanka, however, 88%-90% of energy is thermal energy and transport. This makes the conclusion that among the 12% of energy generation, about 10%-12% of energy is for the electricity generation through solar panels.

"Soorya Bala Sangramaya" (Battle for solar energy) program has given a directive to unlimitedly promote solar energy among Sri Lankan citizens. With the introduction of the program, the aim was created to reach an installed capacity of roof top solar to 200MW by 2020, and hence, free solar consultation is granted by SLSEA registered companies. The interview participants mentioned that Jaffna lagoon has a 4000MW capacity of wind energy generation, which is a higher potential with less energy generation cost, and Mannar region has a 400MW wind generation capacity.

4.3. *ISSUES OF RELYING ON A SINGLE RENEWABLE ENERGY SOURCE AND EMERGENCE OF HRES*

Experts have identified four (04) major issues of relying on a single renewable energy source: Fluctuations and seasonal variations, Non-reliability and inconsistency, Higher cost, and Lack of storage.

Through the expert opinions, it was identified that the strategies followed to mitigate issues of relying on a single renewable source were hybrid renewable energy systems, promoting batteries and storage, merging renewables with other energy sources, and choosing constantly available renewable energy sources. Among them, the hybrid renewable energy systems was stated as the best strategy in terms of sustainability and permanency.

In strengthening the hybrid systems, many strategies such as weather forecasting, modelling, regional grid strategy, and local gridding, were identified. The importance of hybrid renewable energy systems were highlighted in terms of addressing future energy deficit problem, reliability and flexibility, energy efficiency and balancing, sustainability, smooth supply, energy security and environment protection, local value additions, space planning, and less energy cost.

4.4. *EMERGENCE OF HYBRID SOLAR-WIND RENEWABLE ENERGY GENERATION APPROACH FOR SRI LANKA*

Many studies have investigated the hybrid renewable energy concept, but limited studies are available on the application of the concept in Sri Lanka. Renewable energy usage as a hybrid may enhance energy design features through coping up with varying user consumption patterns, reliability, and heading to a sustainable environment. The major reasons identified in hybrid approach to be an apprentice concept in Sri Lanka were, lack of expertise, technology barriers, lower funding, and lower industrial professional interest. It revealed that Pattiyapola is the only place where hybrid renewable energy systems are available in Sri Lanka. This is the world's first 100% green energy driven village, which was ultimately a failure with the introduction of grid connectivity to the village. However, the experts believed that the most popular solar and wind hybrid will be more appropriate for Sri Lanka in terms of abundance, no emissions, and lower human involvement.

Regulatory and policy concessions, abundance and availability of maps, environmental friendliness, long term soft loans, and higher number of suppliers, were identified as the enablers in implementing hybrid solar-wind energy generation approach in Sri Lanka. Technology barrier, funding and investment issues, loopholes in wind energy, knowledge gap, unstable government policies, no local manufacturing, no interest about green energy, conventional systems and energy conservation, higher pay back period, and lack of storage, were identified as major barriers. Figure 4 illustrates the identified enablers and barriers with implementing solar-wind hybrid approach in Sri Lanka.

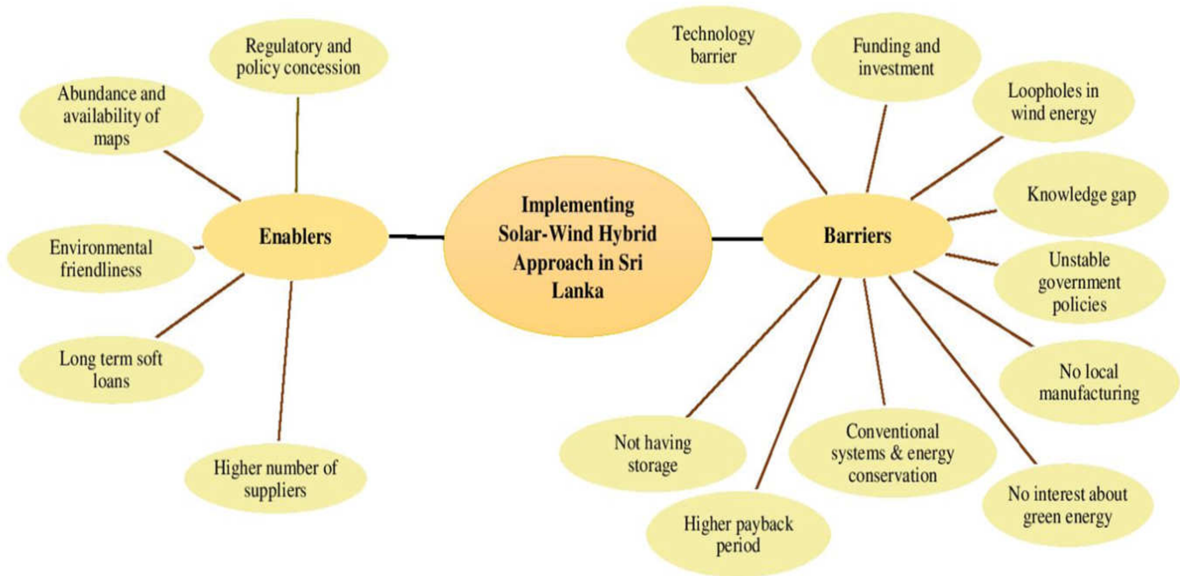


Figure 4: Enablers and Barriers in Implementing Solar-Wind Hybrid approach in Sri Lanka

Furthermore, the study identified three main situations where a solar-wind hybrid approach can be applied in Sri Lanka. Grid connected areas with abundant supply, off grid areas where electricity generation cannot be provided through grid, and for different types of industries such as tea, garment, or cement industries, are the three main situations.

IP2 stated that if all tea factories in Sri Lanka, which is approximately 714 in number, is converted to hybrid energy generating stations, the country can save about 3 - 4 Giga Watt of energy per year. Also, energy generated by combining solar, wind, biomass, and mini hydro, will answer to sustainable tea industry. Funding, incentives, and policy decisions should be improved in order to make more productive. Further, in tea industry, among the major processes of withering, rolling, drying, shifting and grading and packing processes, the drying processes consumes about 4 yards of firewood per day, which is approximately 3.5 trees. Altogether, for the 714 factories in Sri Lanka, it will consume nearly 2500 trees per day, accounting to about 1 million trees per year. This usage of biomass energy for drying process is a huge destruction in terms of forests; therefore, if the drying process can be performed through micro wave and infra-red using electricity generated by solar and wind, it will save about 1 million trees per year for the country. Through a solar and wind hybrid, about 30% of the energy requirement of tea factories can be generated.

5. CONCLUSIONS AND WAY FORWARD

With the worldwide energy challenge and attention towards sustainability and green energy solutions, renewable energy usage plays a major role in the immense process of sustaining energy. It is vital to stand as a nation to face this future energy crisis issue. The effect of being non-reliable and inconstant has made usage of one single renewable energy source to the emergence of a combination of renewable energy sources with a standby source. This was named as “hybrid renewable energy systems,” which has currently become the outcome of triumphs in several research fields that have a remarkable potential in the reliability of integrating solar, wind, and other renewables together. This paper is aimed on investigating the applicability of solar-wind hybrid concept as a sustainable energy solution to the expected future energy deficit in Sri Lanka, where the current practices, competencies and confines in solar and wind energy generation, enablers and barriers while implementing, and the applicability of hybrid solar-wind energy generation approach to the Sri Lankan context, were clearly presented. Finally, the study identified three main situations where a solar-wind hybrid approach can be applied in the country.

6. REFERENCES

Alrikabi, N. 2014. Renewable Energy Types. *Journal of Clean Energy Technologies*, 2(1), 61-64.

Atwa, Y., El-Saadany, E., Salama, M. and Seethapathy, R. 2010. Optimal Renewable Resources Mix for Distribution System Energy Loss Minimization. *IEEE Transactions on Power Systems*, 25(1), 360-370.

Bernal-Agustín, J. and Dufo-López, R. 2009. Simulation and optimization of stand-alone hybrid renewable energy systems. *Renewable and Sustainable Energy Reviews*, 13(8), 2111-2118.

Bernal-Agustín, J., Dufo-López, R. and Rivas-Ascaso, D. 2006. Design of isolated hybrid systems minimizing costs and pollutant emissions. *Renewable Energy*, 31(14), 2227-2244.

Bhattacharyya, S. 2007. Energy sector management issues: an overview. *International Journal of Energy Sector Management*, 1(1), 13-33.

Bull, S. 2001. Renewable energy today and tomorrow. *Proceedings of the IEEE*, 89(8), 1216-1226.

Dagdougui, H., Minciardi, R., Ouammi, A., Robba, M. and Sacile, R. 2012. Modeling and optimization of a hybrid system for the energy supply of a “Green” building. *Energy Conversion and Management*, 64, 351-363.

Dursun, E. and Kilic, O. 2012. Comparative evaluation of different power management strategies of a stand-alone PV/Wind/PEMFC hybrid power system. *International Journal of Electrical Power and Energy Systems*, 34(1), 81-89.

Ehyaei, M., Ahmadi, P., Atabi, F., Heibati, M. and Khorshidvand, M. 2012. Feasibility study of applying internal combustion engines in residential buildings by exergy, economic and environmental analysis. *Energy and Buildings*, 55, 405-413.

Gupta, A., Saini, R. and Sharma, M. 2011. Modelling of hybrid energy system—Part II: Combined dispatch strategies and solution algorithm. *Renewable Energy*, 36(2), 466-473.

Hochmuth, G. 1997. A combined optimisation concet for the design and operation strategy of hybrid-PV energy systems. *Solar Energy*, 61(2), 77-87.

Huang, Y. 2014. Drivers of rising global energy demand: The importance of spatial lag and error dependence. *Energy*, 76, 254-263.

International energy outlook. 2016. [online] *U.S. Energy Information Administration*. Available from: https://www.eia.gov/about/contact/forecasting.php#international. [Accessed 15 April 2016].

International Renewable Energy Agency. 2014. *REthinking Energy*. [Online] IRENA, Abu Dhabi. Available from: https://www.irena.org/rethinking/Rethinking_FullReport_web.pdf [Accessed 15 April 2016]

Johansson, B. 2013. Security aspects of future renewable energy systems–A short overview. *Energy*, 61, 598-605.

Kaabeche, A., Belhamel, M. and Ibtiouen, R. 2011. Sizing optimization of grid-independent hybrid photovoltaic/wind power generation system. *Energy*, 36(2), 1214-1222.

Kellogg, W., Nehrir, M., Venkataramanan, G. and Gerez, V. 1996. Optimal unit sizing for a hybrid wind/photovoltaic generating system. *Electric Power Systems Research*, 39(1), 35-38.

Ministry of power and Energy. 2015. *Sri Lanka Energy Sector Development Plan 2015-2025*. [Online] http://powermin.gov.lk/sinhala/wpcontent/uploads/2015/03/ENERGY_EMPOWERED_NATION_2015_2025.pdf. [Accessed 20 May 2017]

Mohanty, M. 2012. New renewable energy sources, green energy development and climate change. *Management of Environmental Quality: An International Journal*, 23(3), 264-274.

Nema, P., Nema, R. and Rangnekar, S. 2009. A current and future state of art development of hybrid energy system using wind and PV-solar: A review. *Renewable and Sustainable Energy Reviews*, 13(8), 2096-2103.

Pan, J., Ma, H., Zhang, Y. and Mastny, L. 2011. *Green economy and green jobs in China*. World watch Institute, DC:Washington.

Pathak, S. 2014. Energy Crisis, *A Review*. 4(3), 845-851.

Perera, A., Attalage, R., Perera, K. and Dassanayake, V. 2013. Designing standalone hybrid energy systems minimizing initial investment, life cycle cost and pollutant emission. *Energy*, 54, 220-230.

Pérez-Lombard, L., Ortiz, J. and Pout, C. 2008. A review on buildings energy consumption information. *Energy and Buildings*, 40(3), 394-398.

Pradeepkumar, M.S., Azhagiri, M.P., Senthilkumar, T. and Kumaragurubaran, B., 2016. Generation of Electrical Energy Using Hybrid Energy of PV Solar Cell, Wind Turbine, Rain Water and Perpetual Motion. Imperial *Journal of Interdisciplinary Research*, 2(6), 1512-1521

Rahman, M., Khan, M., Ullah, M., Zhang, X. and Kumar, A. 2016. A hybrid renewable energy system for a North American off-grid community. *Energy*, 97, 151-160.

Rezaie, B., Esmailzadeh, E. and Dincer, I. 2011. Renewable energy options for buildings: Case studies. *Energy and Buildings*, 43(1), 56-65.

Shafiee, S. and Topal, E. 2009. When will fossil fuel reserves be diminished?. *Energy Policy*, 37(1), 181-189.

Sri Lanka Sustainable Energy Authority. 2013. [Online]. *Sri Lanka Energy Balance*. Available from: http://www.info.energy.gov.lk/content/pdf3/2013%20Energy%20Balance.pdf [Accessed 25 May 2017]

Tan, W. 2002. Practical research methods. 1st ed. Prentice Hall, Jurong

The Outlook for Energy: A View to 2040, 2016. 2016. [online] *Exxonmobile*. Available from: http://cdn.exxonmobil.com/~/media/global/files/outlook-for-energy/2016/2016-outlook-for-energy.pdf [Accessed 25 May 2017]

Vidyarthi, H. 2014. An econometric study of energy consumption, carbon emissions and economic growth in South Asia: 1972-2009. *World Journal of Science, Technology and Sustainable Development*, 11(3), 182-195.

Wang, X., Palazoglu, A. and El-Farra, N. 2015. Operational optimization and demand response of hybrid renewable energy systems. *Applied Energy*, 143, 324-335.

Wijayatunga, P. 2014. Regulation for renewable energy development: Lessons from Sri Lanka experience. *Renewable Energy*, 61, 29-32.

Wijayatunga, P. and Prasad, D. 2009. Clean energy technology and regulatory interventions for Greenhouse Gas emission mitigation: Sri Lankan power sector. *Energy Conversion and Management*, 50(6), 1595-1603.

Withanaarachchi, A., Nanayakkara, L. and Pushpakumara, C. 2015. Mitigating Climate Change via Non-Conventional Renewable Energy: Case of Sri Lanka. *Journal of Clean Energy Technologies*, 3(5), 372-377.

World Bank. 2013. [online]. *The World Development Indicators*. Available from: http://databank.worldbank.org/data/download/WDI-2013-ebook.pdf, [Accessed 25 November 2016]

World Energy Outlook. 2010. [Online]. *International Energy Agency*. Available from: http://www.worldenergyoutlook.org/media/weo2010.pdf, [Accessed 25 November 2016]

World Energy Outlook. 2015. [Online]. *International Energy Agency*. Available from: https://www.iea.org/Textbase/npsum/WEO2015SUM.pdf, [Accessed 25 November 2016]

Yang, H., Wei, Z. and Chengzhi, L. 2009. Optimal design and techno-economic analysis of a hybrid solar–wind power generation system. *Applied Energy*, 86(2), 163-169.

Yin, R. 2011. *Qualitative research from start to finish*. 1st ed. Guilford Press, New York

Ying, J. 2007. Powering progress-China's clean energy revolution. *Renewable Energy World*, 10(1), 64.

INCORPORATING FACILITY MANAGERS INTO THE DESIGN AND CONSTRUCTION PHASES TO ENHANCE BUILDING PERFORMANCE

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ABSTRACT

Facilities Management (FM) is a relatively new discipline that envelops many essential areas of the built environment. Facility Manager concerns both optimising building performance and ensuring success of the project. Direct incorporation of the Facility Manager into design and construction phases have potential to reduce many problems during the operational phase of buildings. However, many professionals are still unclear on the roles of Facility Manager in the design and construction phases and hence, their potential contribution during these stages. Therefore, aim of this paper was to investigate the potential for incorporating of Facility Managers into design and construction phases of building to enhance building performance. A critical review of literature was carried out for the purposes of understanding roles and essential functions of Facility Manager into design and construction phases.

The case study approach was used to identify the current involvement of Facility Manager in design and construction phases. Moreover, barriers that restrict the involvement of the Facility Managers in the design and construction phases in the current context are also identified. The findings of this research are useful to promote the incorporation of a Facility Manager into design and construction phases in order to enhance quality and performance of buildings.

Keywords: *Construction Phase; Design Phase; Facilities Management; Facility Manager.*

1. INTRODUCTION

The FM is an essential function consisting with a series of linked activities demanding a requirement to coordinate all activities related to planning, design, construction and management of an organization’s physical resource. Building life cycle from a Facility Manager’s point of view does not begin after a building is handed over, but in initial phases where preventive actions can be taken to look after the building with more sensitivity and commitment during operation phase (Shah, 2007).

Furthermore, Aghbar (2011) affirmed that Facility Management is not just about the operation and maintenance phases of buildings. It involves many activities which must be done during the design and construction phases of buildings. The ability of a Facility Manager can help to deliver a high performance building environment, which is largely accounted by initial design, construction and commissioning activities (Hao, et al., 2010). Moreover, from the beginning of building lifecycle maintenance serves as an important undertaking to remove or minimize all undesirable influences as severe faults and defects. Therefore, maintainability is considered as a significant aspect that should be considered right from the early stage of design and construction (Chew, et al., 2004). Meanwhile, Latham (2001) says that, Facility Manager is the eyes and ears of the clients. Therefore, incorporation of Facility Manager should exist during design and construction (John and Croome, 2005).

Hodges (2005) has contended that FM integration into design and construction phases will extend the building lifetime as well as enhance the satisfaction of users, increase productivity and reduce the damaging effect on the environment. Similarly, Akadiri, et al. (2012) have highlighted that, interaction is essential between design

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and construction phases and Facility Manager. This paper initially provides a comprehensive literature review on the importance of the involvement of Facility Manager during design and construction phases. Then, findings of case studies are presented to discuss the roles and functions of a Facility Manager during design and construction phases. Finally, conclusions are drawn from the findings.

2. LITERATURE REVIEW

2.1. ROLES OF FACILITY MANAGER IN LIFE CYCLE PHASES OF BUILDING

The Facility Manager’s role spans from acquisition, design and construction to operation of properties (Nerija *et al.*, 2008). During these phases, Facility Manager will have a role to support initial brief definition, and how various measures are implemented to reduce operating costs and also to deliver most sustainable performance of building (Amaratunga, 2000). According to Jensen (2008c), Facility Manager not only involves during operation phase of building, but also have to have a role in other phases of a building. This can be further specified in relation to different phases of a building project as shown in Table 2.

Table 2: Facility Manager in Life Cycle Phases of Buildings

Building project phase	FM-specific functions
Decision	Incorporating real estate strategies Information on space needs etc. Estimation of impacts on cost of FM
Briefing	Organization of user involvement Formulation of considerations for operation and sustainability Overall requirements for documentation
Design	Incorporation of considerations for operation, sustainability and user needs Formulation of operational concept Formulation of requirements for building automation system
Construction	Interior planning Prepare commissioning Contracting-out operational tasks
Occupation	Move Handling former building(s) Implementation of operational procedures

(Source: Jensen, 2009)

2.2. ROLE OF FACILITY MANAGER IN DESIGN PHASE OF HIGH RISE BUILDINGS

The Facility Manager who is not conversant with the design concept employed by the developer oftern faces challenges in making any critical decisions (Alexander, 2009) such as space expansion, division and remodelling. Conversely, early involvement of a Facility Manager with design team will result in procuring a facility that could be maintained and managed easily (Kok, 2013). If FM integrated with design team will make a greater result on enhancing functionality, sustainability, economy, time, and maintainability of projects (Mohammed and Hassanain, 2010). Ashworth (1989) mentioned that, most of construction faults results from design errors and omissions or carelessness. While building technology systems and level of system integration may occur in design phase of a new building and many decisions will be left to the Architect and Engineers, Facility Managers actively involve in building design and the systems integration effort for it to succeed (Sinopoli, 2010). Furthermore, design of a building has a major impact and influence on operational performance of a building (Silva and Ranasinghe, 2010). However, it does not happen because designer does not understand the remit. Figure 1 shows the actual place of a Facility Manager in the design phase

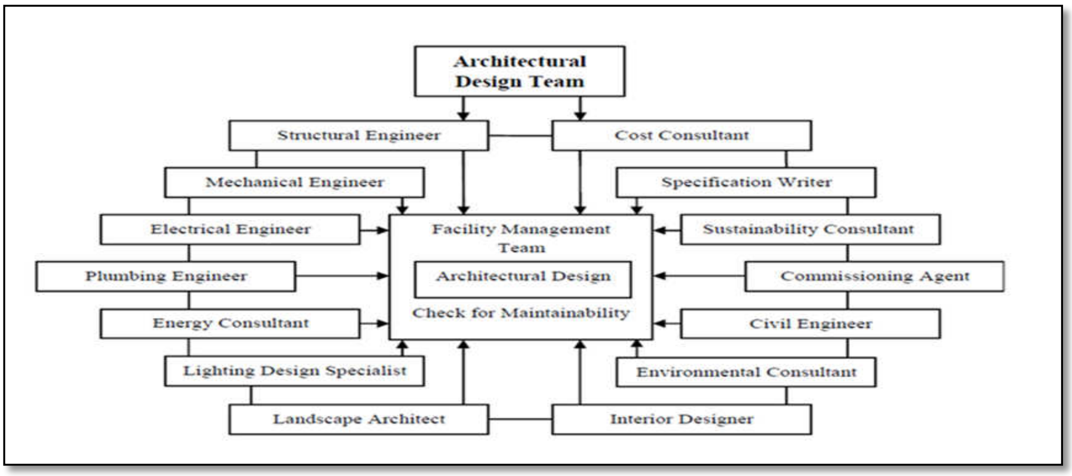


Figure 1: Role of Facility Manager in Design Team

(Sources: Mohammed and Hassanain, 2010)

2.3. BARRIERS FOR INVOLVEMENT OF FACILITY MANAGERS IN DESIGN PHASE

The barriers to the involvement of Facility Manager into design process mainly depends on cost. When procuring a facility, budget usually will look at most cost effective option and Facility Managers may be powerless against decision making expert when the consequences of their actions have significant implication for the facility to be procured (Enoma, 2005). Moreover, there is usually conflict between commercial needs of client and operational needs of the facility provided. In most facilities, there is belief in construction industry that client is often not occupier and so there is no need to involve the Facility Manger (Jensen, 2009). However, to improve value for money, project team must define clearly the needs of client, eliminate unnecessary expenditure and obtain optimum balance between cost, time and quality (Kok *et al.*, 2011).

2.4. ROLE OF FACILITY MANAGER IN CONSTRUCTION PHASE OF HIGH RISE BUILDINGS

The construction phase environment is generally viewed as being distinctive from other phases due to the number of unique characteristics. Such as, immobility, complexity, durability, low technology and high cost (Senaratne and Sexton, 2003). The implications of a Facility Manager in the construction phase of the building can bring motivation and appropriate criteria for successful project specific focus on to the project quality, time and cost. A significant task of construction-related FM is to ensure on-going data consistency from the construction to the operation phase (Moos, 2009). Besides, Roper and Payant (2014) have highlighted that, if the Facility Manager incorporate in construction phase, the project will be constructed on time and within budget. Meanwhile, Facility Manager must be of concerned factors as building system, maintainability, operating cost energy management, staffing and organizing, as built drawings/ models, warranties and sample books (Senaratne and Sexton, 2003). RICS (2006) stated that, Facility Manager should have a clear understanding of construction process. Moreover, competent of property and corporate management, construction technology and environmental services will be required for a Facility Manager (RICS, 2006).

2.5. BARRIERS FOR INVOLVEMENT OF FACILITY MANAGERS IN CONSTRUCTION PHASE

The construction of a facility, either a new building or major refurbishment, will deliver agreed designs. Role of a Facility Manager during this phase is limited (Sinopoli, 2010). Most of the FM professionals' point of view is that FM has traditionally been regarded as poor relations with Architecture, Engineering and Construction (AEC) professions. Total FM only practiced in UK and Europe, is that it cannot be adequately integrated with a client organization without a lengthy contract (for feasibility). This may be a barrier to longevity of Total FM (Atkin and Brook, 2005).

3. RESEARCH METHOD

The research commenced with literature synthesis to locate the roles and essential functions of a Facility Manager during design and construction phases of high rise buildings. By using the literature findings, theoretical framework was developed. The qualitative approach was adopted as best suitable method for research among construction industry professionals working in Sri Lankan construction firms to ascertain their perception on incorporation of Facility Managers into design and construction phases of buildings in order to enhance building performance. Semi-structured interviews were used as a technique to collect data under qualitative approach. Four (04) professionals who are directly involved in construction projects were interviewed in each selected cases by means of semi structured interviews. Altogether, 12 interviews were conducted and each normally lasted for 45 minutes to one hour. Content analysis method was used to analyze data collected through semi structured interview, in order to arrive at suitable conclusions and recommendations. In order to derive patterns to present the information, this research was used the NVivo10 software programme. Finally, arrived at conclusions and recommendations. The Table 1 illustrates the details of interviewees.

Table 1: Details of the Interviewees

Case	Respondent	Designation	Years of Experiences
Case 01	A-01	Senior Manager: Facilities Management	20 Years
	A-02	Project Manager	28 Years
	A-03	Health and Safety Engineer	15 Years
	A-04	Electrical and Mechanical Engineer	12 Years
Case 02	B-01	Facility Manager	20 Years
	B-02	Project Manager	40 Years
	B-03	Safety Engineer	23 Years
	B-04	Architect	12 Years
Case 03	C-01	Project Manager	18 Years
	C-02	Chief Engineer	15 Years
	C-03	Health and Safety Engineer	18 Years
	C-04	Licentiate Architect and Chartered Town Planner	25 Years

4. RESEARCH FINDINGS AND ANALYSIS

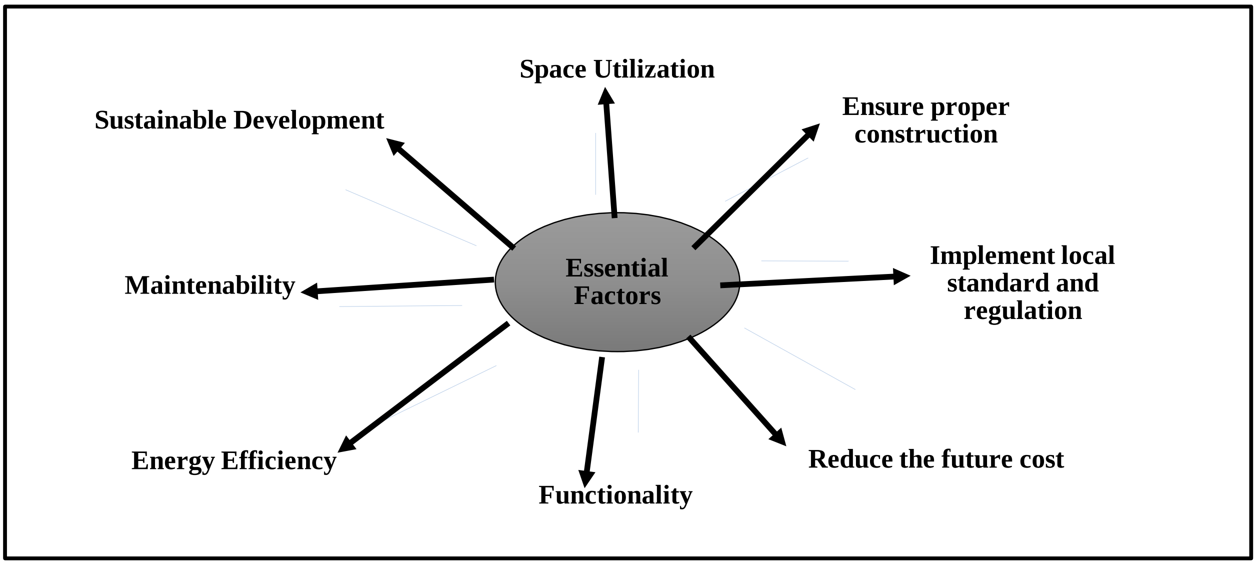
4.1. CURRENT PRACTICE OF FACILITY MANAGER IN DESIGN PHASE

Current involvement regarding Facility Manager into design phase is not well established in the Sri Lankan construction industry. Instead, there is a tendency in the field to appoint a technical person involved in design phase of building as a Facility Manager of that particular building later on. In the current practice, the Facility Manager’s involvement in design phase is very rare. Anyhow, Facility Manager’s involvement during design phase is there even in the Sri Lankan construction industry. Even though, most of the respondents refused to agree that Facility Manager’s involvement is needed in the design phase, when considering Sri Lankan construction industry, it has not been well developed yet. Conversely, some projects have engaged Facility Managers and realised the value of them. However, most of the time, a Facility Manager was not engaged during design phase of building. According to the empirical findings, every expert agreed that a Facility Manager is essential in the design phase, even though it cannot be seen in practice. This is a situation that should be changed because having a Facility Manager in design phase is beneficial for building operational performance (refer section 2).

4.2. *ESSENTIALITY OF FACILITY MANAGER IN DESIGN PHASE*

In many respondents' view, Facility Managers are professionals who are responsible for managing buildings once construction is completed. In Facility Managers' point of view, professionals responsible for operation and maintenance phases should be there from the design phase in order to fulfil the objectives in an effective manner and to add value to the whole project. Furthermore, in order to reduce future problems which will arise mainly during the operation phase, well experienced Facility Manager in the field of building operation and maintenance should be engaged during the design phase. Figure 2 elaborates the main factors supporting this essentiality to incorporate a Facility Manager in the design phase.

Figure 2: Essentiality of Facility Manager in Design Phase



4.3. *KEY FUNCTIONS AND TASKS OF FACILITY MANAGER IN DESIGN PHASE*

When considering functions, it can be identified as areas which are performed by a Facility Manager in the design phase. The functions were highlighted through revealed empirical findings which were preferred by respondents to be performed during the design phase by Facility Managers (Refer Table 3).

Table 3: Key Functions and Tasks of Facility Manager in Design Phase

Functions	Tasks
• Maintenance • Operation • Documentation • Life Cycle Cost • Health and Safety • Material Selection • Guidance • Procurement of Material • Cost Management • Energy Management	• Review of drawings • Review of tenders • Inspection on design team • Review of specification • Preparing life cycle costing • Review of alternatives • Train staffs and workers

4.4. *CURRENT PRACTICE OF FACILITY MANAGER IN CONSTRUCTION PHASE OF THE BUILDING*

It was found that even in construction phase, a Facility Manager's involvement is very rare, even in companies involved in both construction as well as management of properties. Many such companies have developed construction experts to perform operation or building management functions. So such a company will have their in-house resources which can be deployed or can be shared among construction and operation. However, other companies, who are just involved in property management, may not have the opportunity to have Facility Managers involved in the construction phases. Moreover, even on occasions where the project teams include

Facility Managers, their actual involvement in construction phase of projects is less. Likewise, there was general agreement among professionals that Facility Manager's involvement is rare in the Sri Lankan construction industry.

4.5. ESSENTIALITY OF FACILITY MANAGER IN CONSTRUCTION PHASE OF THE BUILDING

The construction phase is an essential phase in the building life cycle where new projects which are already planned and designed are actually developed. It is done with the involvement of many professionals and experts sometimes including or excluding a Facility Manager. From empirical findings it was clear that most of the professionals involved in construction process will not be doing work after completing the construction. Facility Manager is the person who will be working when the construction is completed and will be maintaining and operating the building. Thus, Facility Managers will face many difficulties if the project did not identify and eliminate errors during construction which is not visible prior to building occupation. The findings revealed several areas where Facility Manager's involvement becomes essential during the construction phase (refer Figure 3).

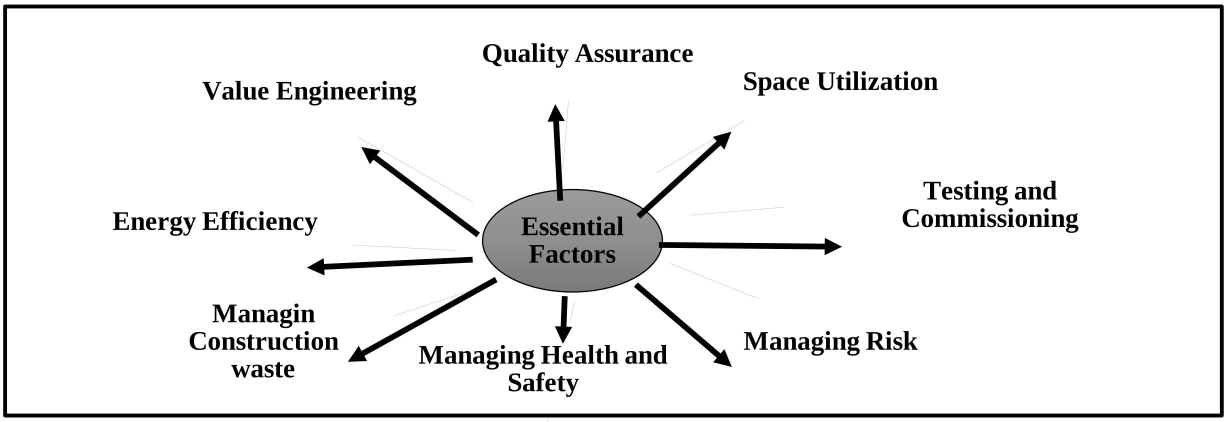


Figure 3: Essentiality of Facility Manager in Construction Phase

4.6. KEY FUNCTIONS AND TASKS OF FACILITY MANAGER IN CONSTRUCTION PHASE

The study revealed the key functions and tasks which are performed by Facility Managers during the construction phase. Table 4 indicates the key functions that should be performed by a Facility Manager during the construction phase.

Table 4: Key Functions for Facility Manager in Construction Phase

Functions	Tasks
• Managing project • Risk Management • Value Engineering • Waste Management • Quality Assurance • Documentation • Testing and Commissioning • Health and Safety Management • Human Resource Management • Defect Rectification • Performance Management • Emergency Evacuation and Fire arrangement	• Site inspection • Testing of services • Report defect and fault • Handling documents • Measuring the quality • Preparation for testing and commissioning • Go through the changes • Authority changes • Service area agreements • Preparing policies • Preparing quality assurance report • Alternative review of value engineering • Review of drawings • Monitoring Waste Management

4.7. *BARRIERS TO ENHANCE THE INVOLVEMENT OF FACILITY MANAGER INTO DESIGN AND CONSTRUCTION PHASES*

The barriers which were extracted from the empirical findings are illustrated in Figure 4. Armstrong (2005) stated that without a Facility Manager in design and construction phases, lots of significant issues can be occurred. By observing non-Facility Managers and Facility Managers' points of views, it was clear that the biggest challenge to the involvement of Facility Managers is unawareness regarding their essentiality in design and construction phases. This makes many combined problems as developer's choice of Facility Manager will be limited since he/she thinks it is nothing but an unnecessary cost. Moreover, it leads to limit the Facility Managers' involvement to after a building project is completed rather than from design and construction phases itself. This in turn can make a building hard to maintain leading to high energy costs.

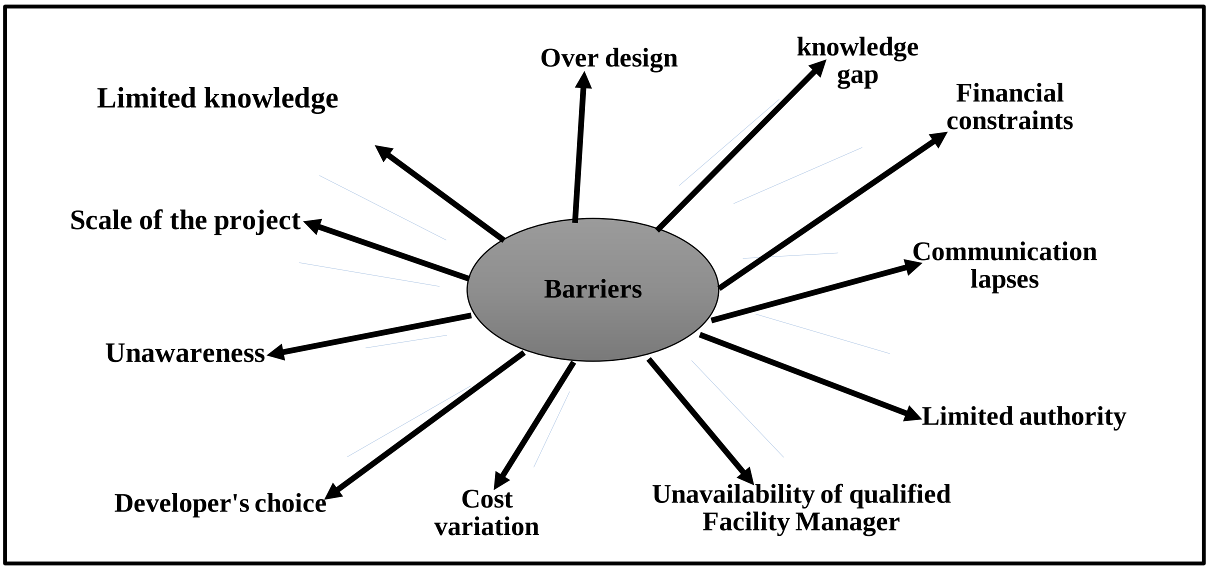


Figure 4: Main Barriers to Incorporate a Facility Manager into Design and Construction Phases

Another identified barrier as highlighted by both Facility Managers and non-Facility Managers is the knowledge gaps of Facility Managers as they are not experts in some essential fields. But, at times it requires comprehensive knowledge in some fields related to the project. This challenge must be won by a Facility Manager by some means.

The remedies which can be used to overcome those barriers are rather similar in both views. Both parties suggested various marketing tools to inform rest of the world about Facility Managers role in design and construction phases. Many problems arise due to unawareness in the industry about Facility Manager's role in design and construction phases of the buildings. However, this challenge cannot be solved in the short run. Conducting promotional seminars and symposium will help to remove the unawareness about Facility Manager's incorporation into design and construction phases to some extent. Once all the unawareness is eliminated, there will be a demand for Facility Managers in design and construction phases. With regard to knowledge gaps it is Facility Managers' responsibility to fill up the lapses. Involving a Facility Manager and giving a rightful position will eliminate other challenges which they have pointed out. The reasons for barriers to incorporate a Facility Manager into design and construction phases are mainly cost and unawareness. But in some projects non-Facility Managers agreed that the Facility Manager can help with reducing future costs.

It was also noted that Facility Managers themselves should take the initiative in finding jobs in construction industry itself not limiting themselves to jobs in already constructed buildings. It was highlighted that in most cases, Facility Managers are reluctant to work in design and construction phases. This is happening mainly due to a lack of self-confidence. According to the case study findings, this was identified as one of the most common barriers to incorporate a Facility Manager into design and construction phases.

Overall, it was observed that not all these identified challenges are common to all Facility Managers. Overcoming these challenges depend on each Facility Manager who is working in design and construction phases. Furthermore, Facility Managers have to take the necessary action to increase their knowledge and experience in construction industries. This is a better option to overcome Facility Manager's barriers in design and construction phases.

5. DISCUSSION

While having many phases in a building, it is important to get involvement of Facility Manager at right phase if they are involved in a project. As role of Facility Managers and scope are not fully understood by the client or developer, they tend to get Facility Manager after construction or after occupation of building. This is the current practice which has been worked so far. However, necessity to incorporate a Facility Manager into design and construction phases becomes vital to optimize performance of building. From empirical findings it can be shown that for enhancement of building performance, a Facility Manager should be engaged in design and construction phases of the building.

The capabilities and scope of work of Facility Managers mean that their participation can bring many rewards to a project. It does not only provide maintainability or smooth operation, but embraces space planning, health and safety, risk management, meeting standards, energy efficiency, and high productive operation too. However, many clients do not insist that a Facility Manager's role can be very critical on design and construction phase's activities and processes. Depending on the scale, cost and the size of a particular project, Facility Managers must be chosen and involved. However, by looking at all practitioner responses it is clear that there are still gaps to be filled in design and construction process and perhaps a Facility Manager can eliminate them. The interviewees agreed a Facility Manager can perform better if they have chance of going through the project before the building has been made. Weighing up both parties' arguments it can be said that, it will be better if a Facility Manager can involve in the design and construction phases at least as an advisor.

5.1. FRAMEWORK DEVELOPMENT

According to the research findings, a framework can be developed overcoming the identified barriers in order incorporate a Facility Manager into the design and construction phases to enhance the performance of the buildings. The framework is developed addresses the effective incorporation of a Facility Manager into design and construction phases in the Sri Lankan construction industry while mitigating the barriers associated in current practice. Figure 5 shows the essential function which should be considered by Facility Manager during the design and construction phases. Additionally, it interprets the roles which can be performed by Facility Manager. Ultimately, it demonstrates the benefits, which can be achieved by incorporating a Facility Manager into the design and construction phases. Eventually, better performance can be achieved by incorporating a Facility Manager into the design and construction phases.

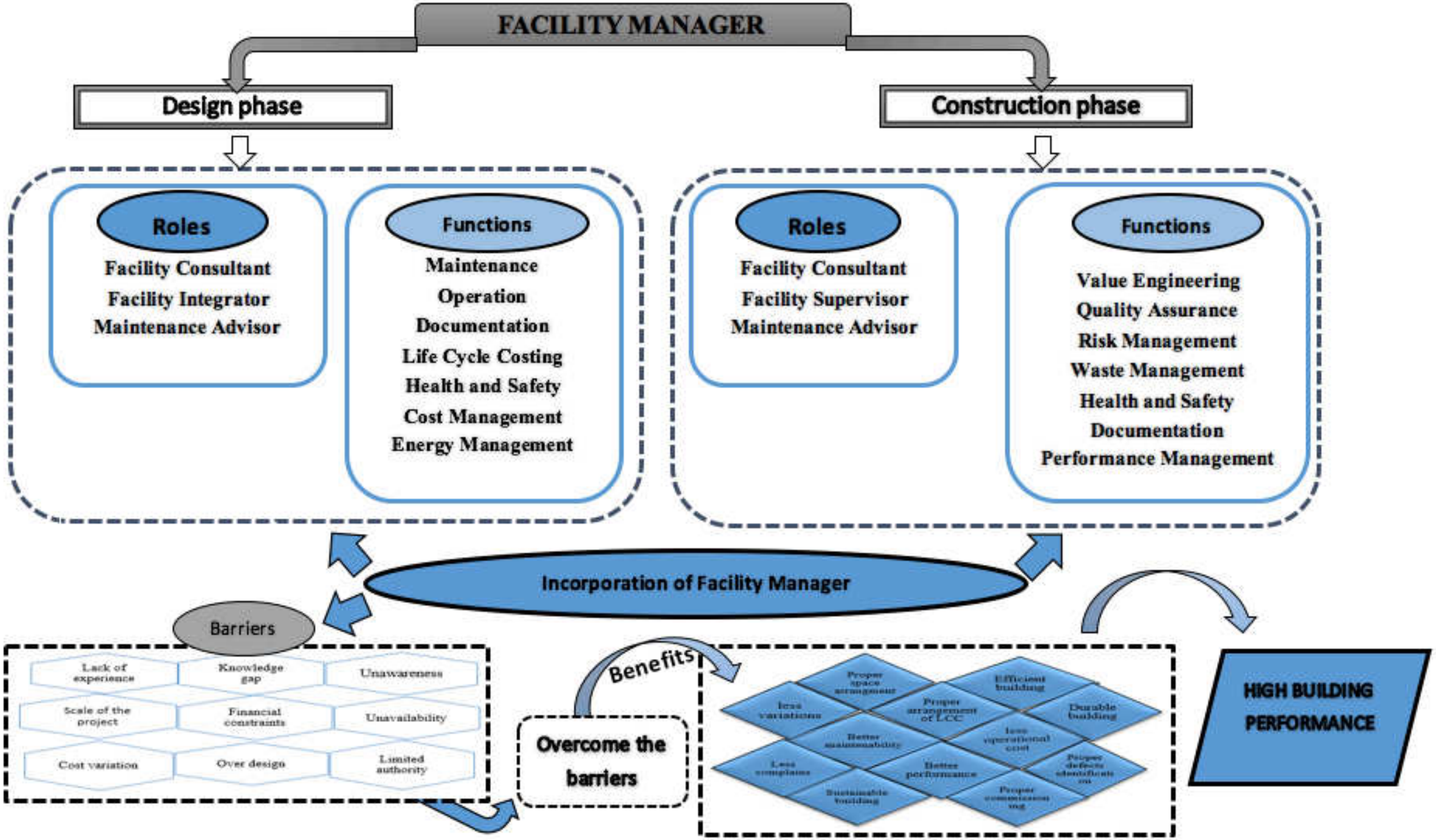


Figure 5: Conceptual Framework to Incorporate a Facility Manager into the Design and Construction Phases

6. CONCLUSIONS

The study has captured the essentiality of Facility Manager's incorporation into the design and construction phases of the buildings in order to enhance the performance of the buildings in the Sri Lankan construction industry. In the current situation, the Facilities Management is not well established in Sri Lanka yet. Consequently, most of the buildings fail to meet the operational objectives because of the improper approaches used during the design and construction phases. The major reason lies in the aforesaid gap between the Facility Manager and initial phases of the buildings. Throughout the literature synthesis, it was clear that the incorporation of Facility Manager is essential concept in the Sri Lankan construction industry. The incorporation of Facility Manager in design and construction phases therefore have been derived from the current practice of Sri Lanka and the involvement were studied from the case studies.

The present situation, in the incorporation of Facility Manager into design and construction phases still not well implemented. Even though, some projects have included Facility Manager into aforementioned phases, there is no framework given to indicate the proper place for a Facility Manager into design and construction phases. In order to eliminate the gap, the research has developed a framework to incorporate a Facility Manager into the design and construction phases of the building in order to enhance the building performance with the involvement of a Facility Manager. The Figure 5 presents the framework to engage facilty managers in the construction industry.

7. REFERENCES

Aghbar, M. A. 2011. Essential information for fm and start professionals, building owners, developer and contractors. *Facilities Management*, 6(11), 300-328.

Akadiri, P., Chinyio, E., and Olomolaiye, P. 2012. Design of a sustainable building: A conceptual framework for implementing sustainability in the building sector. B*uildings*, 33(8), 126-152. doi:10.3390/buildings2020126

Alexander, K. 2009. *Facilities management futures*. Manchester, UK: A Euro FM Publication.

Amaratunga, D. 2000. Assessment of facilities management performance. *Property Management,* 18(4), 258-266. doi: abs/10.1108/02637470010348816

Atkin, B., and Brooks, A. 2005. *Total facilities management* (2nd ed.). Oxford: Blackwell Publishing Ltd.

Ashworth, A. 1989. Life cycle costing: A practice tool. *Construction Enginering, 3*(1), 8-11.

Chew, M., Tan, S., and Kang, K. 2004. Building maintainability-Review of state of the Art. *Architectural Engineering, 10*(3), 80-87. doi:10.1061/~ASCE!1076-0431~2004!10:3~80!

Enoma, A., and Khosrowshahi, F. (Eds.). 2005. *The role of facilities management at the design stage. 21st Annual ARCOM Conference, University of London,* Association of Research in Construction Management.

Hao, Q., Mak, H., Neelamkevil, J., Xie, H., Dickinson, J., Thomas., Pardasani, A., and Xue, H. 2010. System integration and collaboration in architecture, engineering, construction and facilities management. *Advance Engineering Informatics*, 24(2), 196-207. Retrived from http://www.sciencedirect.com/science/article/pii/S1474034609000664

Jensen, P. 2008. Integration of considerations for facilities management in design. In: *Proceedings of the CIB W096 Architectural Management and TG49 Architectural Engineering Conference. 319*, pp. 191-199. Denmark: Design Management in the Architectural Engineering and Construction Sector.

Jensen, P. 2009. Design integration of facilities management. *Architectural Engineering and Design Management, 5*(3), 124-135. Derived from http://www.tandfonline.com/doi/abs/10.3763/aedm.2009.0101#.VZ4f0vlViko

John, G. A., and Croome, D. J. 2005. Contextual prerequisites for the application of ILS principles to the building services industry. *Engineering, Construction and Architectural Management*, 12(4), 356-367. doi: abs/10.1108/09699980510608794

Hodges, C. P. 2005. A facility manager's approach to sustainability. *Facilities Management,* 3(4), 312-324. doi: 10.1108/14725960510630498

Khalil, N., Husin, H. N., Mahat, N., and Nasir, N. 2011. *Sustainable environment: issues and solutions from the perspective of facility manager*. Perak: Elsevier Ltd.

Kok, H. B., Mobach, M. P., and Omta, O. S. W. F. 2011. The added value of facility management in the educational environment. *Facilities Management,* 9(2), 249-266. doi: 10.1108/14725961111170662

Kok, C. C. 2013. Facility management value dimension demand perspective. *Facilities Management*, 11(4), 339-353. doi: org/10.1108/JFM-10-2012-0049

Latham, M. 2001. Classic Facilities Management. *Building*, 12 January 2001.

Mohammed, A. M., and Hassanain, M. A. 2010. Towards improvement in facilities operation and maintenance through feedback to the design team. *The Built and Human Environment*, 3(2), 72-82. Retrieved from http://www.tbher.org/index.php/tbher/article/viewFile/28/29

Nerija, B., Audrius, B., Arturas, K., and Edmundas, K. Z. 2008. Evaluating the life cycle of a building: A multivariant and multiple criteria approach. *The International Journal of Management Science*, 36(6), 429-441.

RICS draft guidance note. 2006. S*trategy, planning and procurement.* Retrieved from Building maintenance: https://consultations.rics.org/consult.ti/building_maintenance/viewCompoundDoc?docid=2724756andpartid=2725076andsessionid=andvoteid=

Roper, K. O., and Payant, R. P. 2014. *The facility management hand book* (4th ed.). United States of America: American Management Association.

Senaratne, S., and Sexton, S. 2003. *Managing chances in construction projects: A knowledge based approach*. UK: Wiley Blachwell Publishing Ltd.

Shah, S. 2007. *Sustainable practice for facilities manager.* 2nd ed. UK: Blackwell Publishing Ltd.

Silva , N. D., and Ranasinghe, M. 2010. Maintainability risks of condominiums in Sri Lanka. *Financial Management of Property and Construction*, 15(1), 41-60. doi: abs/10.1108/13664381011027971

Sinopoli, J. 2010. *Smart building system for architects, owners and builders*. Oxford: UK.

INTRODUCTION OF A SYSTEMATIC PROCESS FOR BUILDING CONTROL IN SRI LANKA

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ABSTRACT

Building Control (BC) contributes significantly to the national economy as well as to the social wellbeing of the public of a country by ensuring the quality of its buildings and their health and safety, structural stability and energy efficiency and by imposing building rules and regulations related to the construction industry of the country. Building work must be properly regulated and monitored by the local authorities during the Plan Approval Process (PAP) by strictly adhering to the relevant building rules and regulations. However, BC in Sri Lanka is fragmented and not well managed due to the low involvement of professionals in the building work and poor supervision of building plan submissions and other related tasks. This condition has led to corruption and malpractices. Therefore, there is a vital need for professionals to get involved in the field, if the existing practises in Sri Lanka are to be changed. The aim of the research was to propose a suitable mechanism for building control in Sri Lanka which will have the involvement of professionals of the country. The effectiveness of the existing system was ascertained through the research objectives. A qualitative research approach was adopted to achieve the research aim through semi structured interviews conducted with 15 professionals coming under five categories. Content analysis was used to analyse the findings and to finally propose a suitable mechanism for building PAP by considering the existing process, identifying the weaknesses in the local practices so that the unfavourable impacts on the current PAP in Sri Lanka could be reduced and corruption and malpractices mitigated.

Keywords: *Building Control (BC); Building Rules and Regulations; Corruption and Malpractices; Plan Approval Process (PAP); Professionalism.*

1. INTRODUCTION

A good quality building should be adaptive, long-lasting, energy efficient, habitable and secure by providing a safe and comfortable internal environment to its occupants (Lowe and Bell, 2000). According to Foolkes (2015), Building Control (BC) can be explained as a quality assurance process that exists from the inspection of the plan to the assessment of the completed work on site, and also as a process that will meet the relevant standards and functional requirements of building regulations. Through BC, building codes and regulations of a building can be identified, the main requirement to ensure the health and safety of the public (Gwin and Seow, 2000). Beggs and Moodley (1997) discuss about the requirement for an environmentally friendly building in order to eliminate its impact on the environment and Pannell (2016) emphasizes on low energy building design technologies in order to minimize energy usage through the use of BC.

Elson (2015) states that the rules and regulations have to be well established in order to maintain the quality and the standards of the buildings introduced under the BC Act. Rumary (2015) emphasizes that apart from establishing rules and regulations, there is also a need to establish a professional body to make BC function more effectively in an accountable and responsible manner. BC bodies are third party accreditors who design, develop, examine and control construction work (Kremer, 2015). According to Morgan (2016), a building surveyor is a unique professional in the construction industry who is in a position to advice and comment on many problems and matters related to sustainability, energy conservation and safety of buildings.

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A knowledgeable professional body has to be established to improve and make the existing procedures more efficient and responsible. “There is a responsibility to shape both the role and the perception of the profession in the wider construction industry” says Foolkes (2015, p.15). According to Conlon (2014), a good education and training will produce professionals of good quality who will be in a position to implement BC well in the construction industry.

Buildings are becoming more and more complex and multifaceted as the complexity of the human needs increases and as the technology advances. Therefore, it is essential to verify whether the new buildings or new construction works are suitable to their locations. Internationally, there has been research done on several aspects of BC such as the training and development of building surveyors in Malaysia (Ali and Woon, 2012), private certification of BC (Pitt, 1984), BC with NHBC (Mills, 1987) and certification of BC in the Netherlands (Meijer and Visscher, 2008). This previous research and also journals have not covered the BC relevant to Sri Lanka. Therefore, there is a necessity for addressing the effectiveness of BC in Sri Lanka and there is also an industry need for research on BC and the need for professionalism in it. Therefore, this research was required to address the literature gap and the industry need.

The aim of the research was to propose a building control mechanism suitable for Sri Lanka with the objectives of identifying the building control practices used by the local authorities in Sri Lanka, identifying the weaknesses in the existing system and to propose suitable suggestions and strategies

2. LITERATURE FINDINGS

2.1. CONCEPT OF BUILDING CONTROL

BC is an important aspect in the construction industry (Wood and McGahey, 1995). It covers a wide area relating to building work in the construction sector towards upgrading the living standards of the public and ensuring their health and safety (Thompson, 2015). According to Everall (2015), BC is a process which provides a large package of services to ensure the structural stability of buildings, the health and safety of the public and the sustainability of the buildings.

Energy efficiency buildings (Smith, 2016), sustainable buildings and environmentally friendly buildings (Beggs and Moodley, 1997) are the buildings that come under BC and ensure energy saving. According to Sariola and Kukkonen (2006), by limiting the impact of buildings on the environment and highlighting the areas where the use of scarce resources could be reduced or minimized, it may be possible to ensure the quality of a building. Building codes (Gwin and Seow, 2000, p.23), resistive designs and the recognition of dangerous structures (Edmonds, 2015) are other attainable objectives of BC that will ensure public health and safety, and also the general welfare of the occupants of a building. Bridgland (2015) explains that the health and safety of the public mainly depends on the building standards and on the reliability of the assessments done on building services and building work. Therefore, in order to ensure these, a regulatory body will have to be established for BC.

2.2. LEGAL BACKGROUND

According to Baiche *et al*. (2006), regulations and standards are a dominant part of BC that will conserve and uphold the quality and performance of new or existing constructions. BC surveyors should follow building regulations and legislation to ensure that houses, commercial buildings and other buildings are designed and constructed so as to ensure the safety of the public (Wood and McGahey, 1995). BC regulations should cover areas such as public health, building pathology, energy conservation and sustainability, fire safety and building accessibility (King, 2016).

2.3. BUILDING CONTROL PROCESS

Aarons (2014) argues that BC involves an application process, commencing from the submission of the planning application and ending with the issuing of the BC completion certificate which has to be before the commencement of the construction work. It can be identified mainly as PAP.

As stated by Wilson (1988) and Pitt (1984), the BC procedure identified as PAP initially includes an approved inspection procedure and three alternative BC options for the developers. According to Pitt (1984) and

Billington (1986), PAP in BC may differ from one country to another as it depends on the rules and regulations of the country concerned, and may consist basically of the initial notice submitted, approving of the plan, issuing of the building permit, inspection of the site, and finally the issuing of the certificate of conformity to certify that the construction has been completed successfully.

According to Marsh (2015), before approving the plans for any building or before issuing the completion certificate, the local authority or an appointed inspector has to make sure that the building meets the functional and relevant safety requirements. Therefore, as explained by Baiche *et al*. (2006) it is crucial during the inspection of building construction to assess whether all site operations comply with the building regulations of the country. Pedro *et al*. (2010) explained the types of building control systems that are different from the conventional approving procedure and available for plan approval and site inspection depending as to who is responsible for the work, i.e., a private or a public authority - public building control where public authorities are responsible for plan approval and site inspection, mixed building control where public authorities and private parties share responsibilities and dual building control where the applicant can choose the party who has to conduct the process. Therefore, PAP is mainly concerned about the upcoming construction work in order to maintain the development pattern of the country and to ensure the social well-being of the public.

3. RESEARCH METHODOLOGY

A qualitative approach was adopted for this research as it was necessary to assess subjective data such as professional opinions. Furthermore, to propose a suitable building control mechanism for Sri Lanka with the involvement of professionals, the opinions of professionals were necessary. Therefore, a quantitative approach with rankings and categorization was not necessary for this research as it was based on subjective data. Thus, the qualitative approach was selected as the research approach for this study instead of the quantitative approach or the mixed approach. Two main techniques were adopted to collect data, namely interviews and a document review. The document review was carried out mainly by referring to several documents published by the Urban Development Authority and the local authorities on their approval processes. The intention of the document review was to identify the BC that is currently being practiced in the country and to distinguish its stages, parties involved, and the rules and regulations.

Subsequently, interviews were carried out with fifteen professionals with experience in the construction industry, who came under five categories, i.e., town planners, architects, engineers, quantity surveyors and lawyers. Three professionals from each category were selected to study the BC used by the local authorities in Sri Lanka. The interviews were used to identify the BC currently being practiced in Sri Lanka along with its weaknesses and to propose a suitable new process for building control by addressing the weaknesses of the existing process. The findings from the interviews and the document review were analysed using content analysis software, NVivo (version 11). The scope of the research was confined only to building control in the plan approval process in the pre-contract stage. This study mainly focused on new construction projects and not on projects dealing with renovation or refurbishment.

4. RESEARCH FINDINGS

4.1. *EXISTING PROCESS OF BUILDING CONTROL*

The existing process of PAP was identified through interviews and a document review to achieve the first research objective. Table 1 illustrates the procedure and parties involved at each sub stage along with the activities related to each stage.

Table 1: Existing Process of Building Control

Steps	Procedure
Stage 1 Start of the process	Obtaining clearance from the relevant authorities by the applicant
Stage 2 Submission for preliminary planning clearance	Submitting multiple clearance reports along with the application to the Urban Development Authority or the local authority as the case may be, based on the project scope

Steps	Procedure
Stage 3 Approval for plan clearance by the Urban Development Authority/ local authority	Obtaining the approval from the Urban Development Authority / local authority if the documents have complied with the relevant standards
Stage 4 Submission of the plan for approval	Getting the design certified by professionals such as town planners, architects and engineers
Stage 5 Scrutiny of the application and other documents	Obtaining reports from the relevant government officials (Technical Officer, Public Health Inspector etc.)
Stage 6 Approval (by the Local Authority)	Obtaining the approval for commencement of the work with the concurrence of the Commissioner, Public Health Inspector, Planning Officer, Technical Officer etc., if the documents have complied with the relevant rules and regulations
Stage 7 Approval (Regional Authority/ UDA) by the Planning Committee	Getting the final decision (approval or disapproval) from the special committee comprising the Town Planner, Engineer, Architect, Urban Commissioner and a representative of the relevant authority after considering any problem or an issue that has arisen
Stage 8 Issuing of the building permit	Getting the building permit from the local authority
Stage 9 Issuing of the Certificate of Conformity	Getting the Certificate of Conformity (CoC) from the local authority

According to the findings of the literature review, the Plan Approval Processes used differs from country to country. The basic stages and the work that is carried out under those stages are however almost similar. Furthermore, the parties and the organizations involved in the PAP varied as there was private sector involvement in PAP in other countries.

At present, the applicant has to obtain, in advance approvals from the relevant authorities or the department under whose jurisdiction the building is located, and submit them along with the application to the local authority to obtain preliminary planning clearance. At this stage, the applicant may have to deal with many issues because of the difficulties in obtaining the relevant clearances from the different departments. Thereafter, the design has to be developed and signed by a qualified architect with a qualified engineer certifying the structural and technical details. After the design and other relevant documents have been submitted, the technical officer may conduct an audit to provide a substantiated opinion regarding the extent to which the design has conformed to the technical requirements and the public health inspector may conduct site inspections to verify the health and safety aspects of the new construction work. The opinions of other authorities and design auditors will also be considered, and if the relevant building authority is satisfied, a building permit will be granted to carry out the construction work.

After the completion of the work, the final site inspection has to be carried out before the local authority can issue the certificate of conformity certifying that the construction has been completed successfully. Nevertheless, lack of skills and knowledge of building regulations on the part of building inspectors as well as their ignorance of the required regulations and standards can lead to mistakes. Therefore, the building control inspector needs to be suitably qualified and be ethical in his work to ensure the effectiveness of the building control process and the quality of the work. The degree of involvement of politicians of the local authority in building control is presently high and this can affect the efficiency and the effectiveness of the local authorities concerned making the standard and the quality of buildings questionable. It was revealed that the involvement of professional parties in the Plan Approval Process in Sri Lanka is at a lower level compared with other countries and that there is no specific professional body in the country handling building control. In most of the other countries, there are well recognized bodies called building control surveyors who are responsible for all the stages of PAP and the granting of the final approval for the building.

Due to lack of sufficient manpower in the local authorities, it has become difficult for them to check all the building plans they receive and carry out site inspections prior to the commencement of respective building work. Due to the large number of applications received, small local authorities are unable to manage and handle the building control process in an effective manner and the quality of their inspections could be affected as a result. However, BC in Sri Lanka is fragmented and is not well managed despite the national government as well as the local governments being the authorities responsible for it. As a result, corruption and malpractices have become widespread in the country. Due to its significance to the national and local economies as well as to the social wellbeing of the public, BC has to be properly regulated and monitored. Otherwise, there could be bribery and corruption which is increasingly becoming a concern in the country.

4.2. PROCESSES SUITABLE FOR BUILDING CONTROL DURING PRE-CONTRACT STAGE

The existing practice of building control was first identified from the data published by the authorities, and from the documentary review and was verified thereafter through the interviews. Even though, the building control process is already being practised in Sri Lanka, most of the interviewers stated that the existing PAP needs amendments in order to control the corruption and malpractices in the industry. Through this, several suggestions and strategies were recognized that can enhance the existing practice and thus fulfil the final objective of the research. The PAP that was developed is illustrated in Table 2 and Figure 1 by highlighting the special features obtained through the interviews.

Table 2: Proposed Process for Building Control

Steps	Suggested Procedure
Step 1 Start the process	One stop shop
Step 2 Submission for preliminary planning clearance	One single submission for the preliminary plan approval
Step 3 Approval for plan clearance by the local authority	Obtain the approval from the local authority, if the documents comply with the relevant standards
Step 4 Submission of the plan for approval	Assign the responsibility for the design and construction to the signatories, such as the Town Planner, Architect and Engineer.
Step 5 Scrutiny of the application and other documents	Appoint a third party reviewer to ensure effective results, after receiving the reports from the Technical Officer, Public Health Inspector etc..
Step 6 Approval (by the Local Authority)	Obtain permission to carry out the work by getting the approval from the Commissioner, Technical Officer, Planning Officer, Public Health Inspector etc., if the documents comply with the relevant standards
Step 7 Approval (In Regional Authority/UDA) by the Planning Committee	Getting the final decision (approval or disapproval) in concurrence with the Town Planner, Architect, Engineer, Urban Commissioner and the representative of the relevant authority by considering the issues that have arisen
Step 8 Issuing of the building permit	Authorize private authorities to continuously monitor the process
Step 9 Issuing of the Certificate of Conformity	Make the Building Control Surveyor to be in charge of issuing the Certificate of Conformity

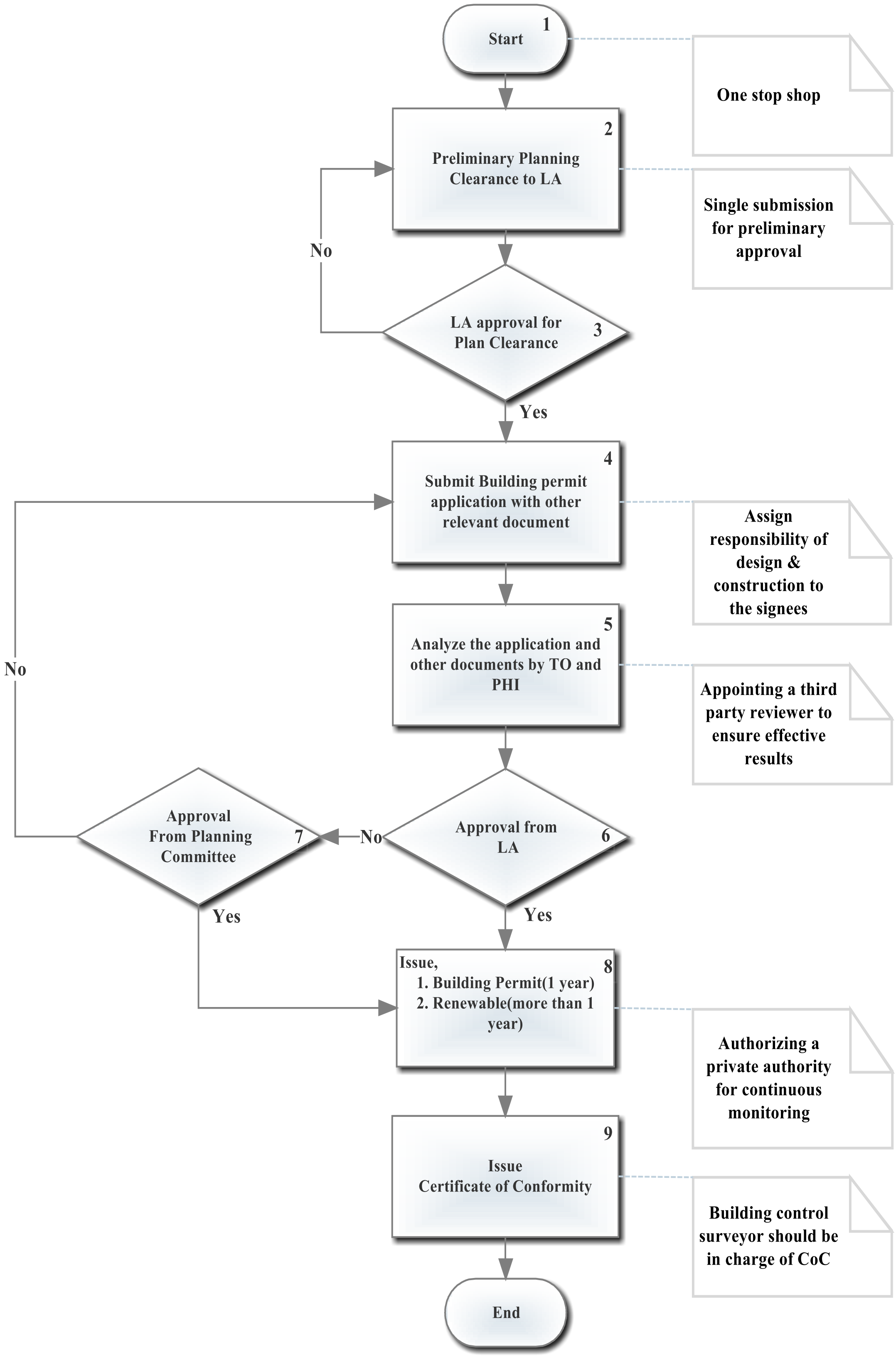

Figure 1: Proposed Plan Approval Process

One stop shop concept has to be practiced as an integrated process with the involvement of all relevant authorities seated at one table, in order to obtain the relevant approvals from one single place and provide written instructions to the applicant. This may increase the effectiveness of the process and provide the approval with the concurrence of all relevant parties after considering all aspects of the building and mitigating malpractices and corruption.

If all the documents comply with the relevant standards, approval will be granted by the local authority. The application for the building permit can be submitted subsequently along with the other relevant documents. There will be high transparency in the approval process at this stage due to the proposed concept of one stop shop. In the current practice, though the design has to be developed and certified by a qualified architect and the structural and technical requirements by a qualified engineer, the architect or the engineer do not have to bear any responsibility or obligation for any future actions related to the design. Therefore, the responsibility for the construction work will not be there, though the design has been developed and certified by a qualified architect and a structural engineer. In order to overcome this issue, the responsibility for the whole construction work from its inception to completion has to be assigned to them. A code of ethics has to be enforced which will provide for blacklisting or punishing of wrongdoers in order to avoid negligence and carelessness on the part of those professionals.

The main duty of the technical officer would be to check the compliance of the design of the proposed building against the building rules and regulations and the main duty of the public health inspector would be to verify the health and safety aspects of the building. Most of the malpractices and corruption take place during this stage. Therefore, the appointment of a third-party reviewer to overcome this issue will ensure the accuracy of the work done by the technical officer and the public health inspector by verifying same and may also help to mitigate corruption and bribery.

A private sector party can get involved to issue the building permit and do site inspections in place of the technical officer or the public health inspector, since most of the other countries get the private sector involved to carry out the building control process and this is found to be more effective in maintaining the standard of the buildings. Those private sector parties have to be registered or should have the authority to issue building permits and carry out site inspections in order to ensure that the construction work complies with the rules and regulations of the country. The quality of the process will have to be assured by means of certifications and therefore a professional such as a Building Control Surveyor has to be introduced to maintain the quality of the final product by getting him to issue the certificate of conformity. It might mitigate the unfavorable impacts when there is little involvement of professionals in the process.

Therefore this research is intended to offer a solution to the problems of building control that are currently being experienced and to mitigate bribery and corruption that exists.

Proposed Alternative System – Online System

According to the literature findings, computer intelligence is essential for developing building control in order to increase the latter’s effectiveness, share the knowledge and open up communication facilities all over the world. An online system for PAP was suggested by several interviewees to mitigate corruption and malpractices. The main advantage of introducing an online system is the reduction of paper work that will avoid errors in the documentation and also its ability to make quick updates of the documents whenever they need amendments. Moreover, an online system may help to ensure a specific time period for the PAP and it may also provide the opportunity for an applicant to track the status of his application. An online system may highly influence the effectiveness of the process by making it highly transparent and reducing the likelihood of corruption and bribery. Such a system may provide detailed guidelines for proper documentation and preliminary clearance from the relevant authorities without having to waste time on collecting those documents. It was revealed that there are limitations at present for an online system by way of people’s skills and facilities/ logistics. Therefore, this system will be very expensive and will need an initiative from the government for its implementation.

5. CONCLUSIONS AND RECOMMENDATIONS

Proper BC with the involvement of professionals has become essential for Sri Lanka. With the development of the construction sector, buildings are getting more and more complex and the corruption and malpractices in the construction sector are on the increase. Therefore, BC will ensure the success and quality of a project.

The current practice related to BC in Sri Lanka was identified with respect to the parties involved, rules and regulations and the process itself, by studying the published documents and through a document review and interviews. Nine main stages were identified in the existing building control process. The research subsequently focussed on identifying the ineffectiveness of the current process in Sri Lanka along with corruption, malpractices, health and safety issues, and technical matters that are prevalent. In order to develop a suitable BC mechanism, the role of the professionals in the process was ascertained by obtaining the opinions of the professionals in the construction industry. If the corruption and malpractices are to be mitigated, a proper BC mechanism will have to be ensured by encouraging the professionals to get more involved in the process. Therefore, for each stage a modified version was discussed and an alternative system was introduced. It is recommended to adopt the developed and modified building control process (Refer Figure 1 for the proposed building control process) which comprises of critical suggestions such as: one stop shop, a single submission for preliminary approval, assignment of the responsibility for the design and construction to those who certify them, appointment of a third party reviewer to ensure effective results, authorisation of a private authority for continuous monitoring of the process and having a Building Control Surveyor to be in charge of the issuing of the Certificate of Conformity to mitigate corruption and malpractices and to enhance the effectiveness and transparency of the building control process. To improve transparency, effectiveness and efficiency, it is recommended to increase the involvement of professionals and technically qualified staff at different levels. It is also recommended to have a proper document control and management system.

6. REFERENCES

Aarons, T., 2014. A Balanced approach: The work of the Building Regulations Advisor committee. *RICS Building Control Journals***,** p. 8.

Ali, A.S., and Woon, C.J., 2013. Issues and challenges faced by building surveyors in Malaysia. *Structural Survey,* 31 (1), 35 – 42. Retrieved from: http://dx.doi.org/10.1108/02630801311304404

Baiche, B., Walliman, N., and Ogden, R., 2006. Compliance with building regulations in England and Wales. *Structural Survey*, 24 (4), 279 – 299. Retrieved from: http://dx.doi.org/10.1108/02630800610704427

Beggs, C.B., and Moodley, K., 1997. Facilities management of passively controlled buildings. *Facilities*, 15 (9/10), 233 – 240. Retrieved from: http://dx.doi.org/10.1108/02632779710178776

Billington, M.J., 1986. Building control — An update. *Property Management,* 4 (2), 116 – 119. Retrieved from: http://dx.doi.org/10.1108/eb006616

Bridgland, J., 2015. Safety in numbers: Survey findings reveal an increased awareness of health and safety in the property sector, but issues remain. *RICS Building control Journals,* 8-9.

Conlon, M., 2014. Only the best is good enough: Education and training are key to taking the profession forward. *RICS Building control Journals*, p.4.

Edmonds, C., 2015. Be prepared: Knowledge of the extent and location of sinkholes is vital for briefing developers. *RICS Building control Journals*, p.13.

Elson, S., 2015. Changing liabilities: Tougher fines and sentencing for health and safety breaches are on the way under regulations reforms. *RICS Building control Journals*, 10-11.

Everall, P., 2015. Model Answers: The way that different councils are dealing with the increasing squeeze on services. *RICS Building Control Journal*, 12-13.

Foolkes, A., 2015. Crossing Boundaries: The role of the building control body as part of the project team. *RICS Building Control Journal*, p.14.

Gwin, C. R., and Seow, E. O., 2000. Homeowner warranties and building codes. *Journal of Property Investment & Finance,* 18 (4), 456 – 472. Retrieved from: http://dx.doi.org/10.1108/14635780010345409

King, V., 2016. A more accessible part M: the implications of recent changes to Part M. *RICS Building Control Journal.* P.7

Kremer, O.R., 2015. Training for the future: Evolution of building control in Israel. *RICS Building Control Journal*, p.5.

Lowe, R., and Bell, M., 2000. Building regulation and sustainable housing. Part 2: technical issues. *Structural Survey*, 18(2), 77 – 88. Retrieved from: http://dx.doi.org/10.1108/02630800010330121

Marsh, T., 2015. Fit for occupation: Consultation with the fire service is integral to ensuring that safety duties have been satisfied. *RICS Building control Journals,* p.14.

Meijer, F. and Visscher, H., 2008. *Proceedings of COBRA 2008*: Building regulations from an European perspective. *The Construction and Building Research Conference of the Royal Institution of Chartered Surveyors,* RICS, London.

Mills, G.C., 1987. Building control with NHBC. *Structural Survey,* 5 (4), 335 – 339. Retrieved from: http://dx.doi.org/10.1108/eb006264

Morgan, M., 2016. New Wheels: Energy conservation and generation issues. *RICS Building Control Journal*, 14-15.

Pannell, R., 2016. Closing the gap: Initiatives under way to solve the energy performance gap in new homes. RICS Building Control Journal, p.9.

Pedro, J.B., Meijer, F. and Visscher,H. (2010).Building control systems of European Union Countries. *International Journal of Law in the Built Environment,* 2 (1), 45 – 59. Retrieved from: http://dx.doi.org/10.1108/17561451011036513

Pitt, P.H., 1984. Private certification of building control. *Structural Survey*, 2 (3), 212 – 215. Retrieved from: http://dx.doi.org/10.1108/eb006186

Rumary, E., 2015. Keeping up to date: the importance of continuing professional development for building control surveyors in the built environment sector. *RICS Building control Journals*, p.8.

Sariola, L., and Kukkonen, E., 2006. Developments of the emission classification of building materials. *Facilities*, 24 (11/12), 430 – 435. Retrieved from: http://dx.doi.org/10.1108/02632770610684918

Smith, P., 2016. Attention to detailing: Internal wall insulation offers opportunities for energy saving, but the choice of product requires care. *RICS Building Surveying Journal,* 20-22.

Thompson, A., 2015. Safe and sound: The role of building control at the Glastonbury festival. *RICS Building Control Journal*, 8- 9.

Wilson, R., 1988. The LDSA and the benefits to builders and developers. *Structural Survey,* 6(3), 203 – 206. Retrieved from: http://dx.doi.org/10.1108/eb006283

Wood, A., and McGahey, G., 1995. The new face of building control. *Structural Survey,* 13 (4), 21 – 22. Retrieved from: http://dx.doi.org/10.1108/02630809510104867

INVESTIGATION INTO THE CURRENT PROJECT RISK MANAGEMENT PRACTICES WITHIN THE LIBYAN OIL AND GAS INDUSTRY

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ABSTRACT

The continued increase in the world's population means increasing global energy demands. According to the best estimates available, hydrocarbons will be the main contributor to meet these energy needs. However, oil and gas projects pose significant risks. The literature shows that many projects in the industry fail as a result of improper risk management practices. This research paper focuses on Libya, an important player in fulfilling the world's energy demands, where the oil and gas industry is crucial to the national economy. Given the conditions existing in Libya, appropriate project risk management for the oil and gas industry needs is important. The aim of this paper is to investigate the current project risk management practices in the oil and gas industry in Libya. Thirteen semi-structured interviews with top managers, project engineers and advisors were undertaken to achieve this aim. The results show that awareness of the concept of project risk management is still very low in Libya and there is a lack of project management culture and risk management in particular. The paper also demonstrates that although these practices are already being applied to some extent, this relies on the prior knowledge and experience of specific individuals, rather than on a systematic, documented procedure. The lack of financial resources and the shortage of experienced and qualified personnel due to the country's current situation and as well as a lack of clear organisational vision within the oil and gas industry in Libya, all limit the implementation of effective project risk management.

Keywords: *Libya; NOC; Oil and Gas; Project Management; Project Risk Management.*

1. INTRODUCTION

The oil and gas sector has been identified as one of the most influential economic sectors due to its significant impact on every aspect of all other businesses (Akinremi *et al*., 2015, Badiru and Osisanya, 2013). The oil and gas industry is one of the most important in the world because its influence does not only structure the economic development of a country, but also affects the development and nature of other sectors (Ajah, 2014). Furthermore, Dayanandan and Donker (2011) have argued that oil is a major resource that has been in great demand, and its effects on national and international financial markets cannot be overlooked. In addition, the largest companies in the world are directly related to the oil and gas industry (Dayanandan and Donker, 2011). According to British Petroleum (BP) (BP, 2016), the need for energy will continue to increase as the world's population increases; they predict that it will increase by approximately 1.5 billion, to reach a total population of 8.8 billion by the year 2035. Hydrocarbons will continue to be the main source of energy (responsible for nearly 80% of total energy sources) in 2035 fuelling the world economy, with the Middle East and North Africa (MENA) region being the main supplier (BP, 2016, IEA, 2015).

The continued need to ensure that projects across the oil and gas sector are managed properly and efficiently has led to increased pressure in both industry and academia to develop reliable project management strategies to reduce project failure; project risk management has been identified as a key factor to ensure project failure is minimised (Al Subaih, 2015, Rabechini and de Carvalho, 2013, Rogers and Ethridge, 2013, Salazar-Aramayo *et al*., 2013, De Carvalho and Rabechini, 2015, PMI, 2013, Zwikael and Ahn, 2011).

Studying project risk management in the oil and gas sector is vital because the industry is risky. It involves a large number of stakeholders, is technologically difficult, is fitted to tight budgets and schedules and

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incorporates a large amount of uncertainty as a result of incomplete information, particularly during the exploration stages (Briel *et al.*, 2013, EY, 2015, EY, 2014, Deloitte, 2015).

Within the context of Libya, the oil and gas sector contributes significantly to the Libyan economy; indeed, approximately 96% of the government revenue comes from oil and natural gas (EIA, 2015). Libya has the largest established proven crude oil reserve in Africa (9th worldwide) and the fifth-largest natural gas reserve in the continent (see Figures 1 and 2); it has been a member of the Organization of Petroleum Exporting Countries (OPEC) since 1962 (EIA, 2015). Exploration for oil in Libya started in 1955; the petroleum law No. 25 was enacted in April of the same year. The first oil fields were discovered in 1959 at Nasser, and Libya began oil exports in 1961 (Inkpen and Moffett, 2011, EIA, 2015).

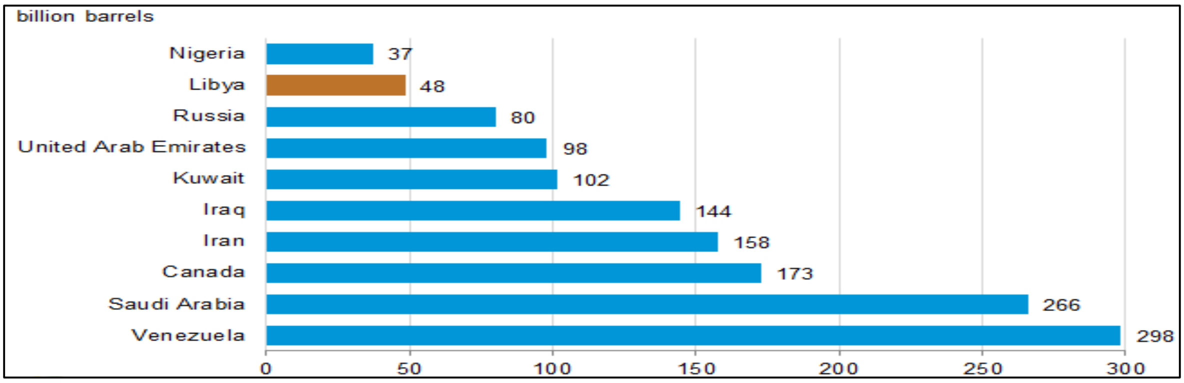

Figure 1: The World's Top 10 Holders of Proved Crude Oil Reserves (EIA, 2015)

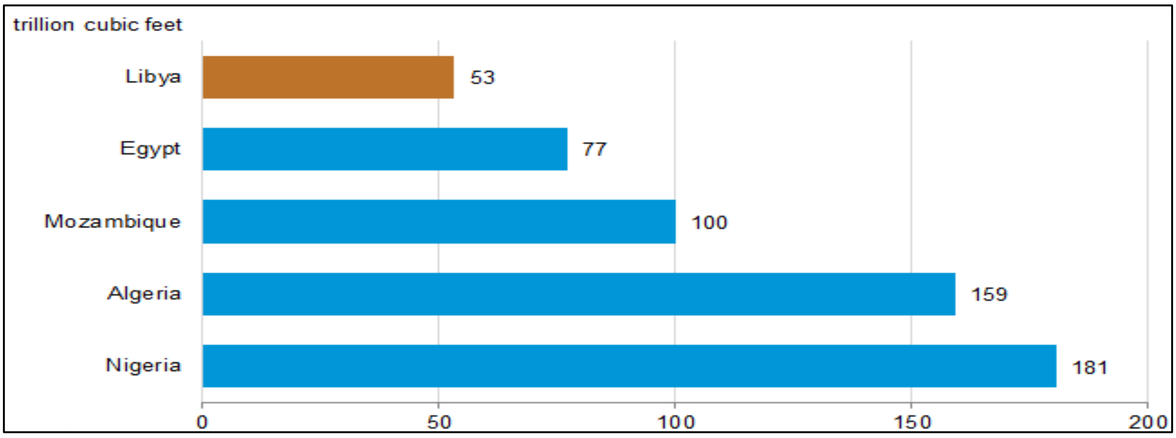

Figure 2: Top 5 Holders of Proven Natural Gas Reserves in Africa (EIA, 2015)

Apart from being the largest oil producer in Africa, Libya is also among Europe’s largest North African oil suppliers. Libya has vast oil reserves that allow it to produce oil for domestic and export purposes (Miyoshi, 1999). Libya’s economy is built on oil, and exports contribute greatly to the nation’s overall revenues (Otman and Karlberg, 2007).

Therefore, the oil and gas industry plays a very important role in Libya, as this not only makes it the leading oil country in Africa, but also helps to boost its economy. Oil and gas as a natural resource has helped Libya to maintain its autonomy despite the blows caused by the sanctions imposed upon the country (Brown, 2014).

Accordingly, this research paper investigates the current project risk management practices in the oil and gas industry in Libya. The structure of this paper is as follows:

- Literature review on the topic of project risk management with particular reference to the oil and gas industry
- Methodological considerations and data analysis
- Findings and discussion
- Conclusions

2. LITERATURE REVIEW

2.1. PROJECT RISK MANAGEMENT

Risk management is becoming widely implemented in various industries and societies. It is now generally accepted that risk cannot be eliminated, but rather can be managed. Risk management provides a framework to gain a balance between avoiding accidents and catastrophes and providing opportunities (Aven *et al*., 2007). According to Besner and Hobbs (2012), project risk management is defined as an organised practice to manage project risks effectively.

Hence, the main goals of risk management are to guarantee the rapid identification of risks and to establish a clear process of assessment, action planning and later reporting of the identified risks. As well, it is vital to stress the identification of opportunities that will certainly have an effect on the decision-making process (Burtonshaw-Gunn, 2009).

Project risk management is a valuable element of project management, as it augments the effectiveness of the other project management processes; it offers support when employed alongside other good practices (Besner and Hobbs, 2012, Benta *et al*., 2011, PMI, 2013). Currently, project risk management aims to recognise project challenges in multicultural environments, particularly those associated with increasingly global and complex contexts (Thamhain, 2013).

Figure 3 depicts the project risk management processes, as summarised by the Project Management Institute (PMI, 2013). These practices include the five formal project risk management processes: a) Project risk planning, b) Project risk identification, c) Project risk analysis (quantitative and qualitative), d) Project risk response, and e) Project risk control.

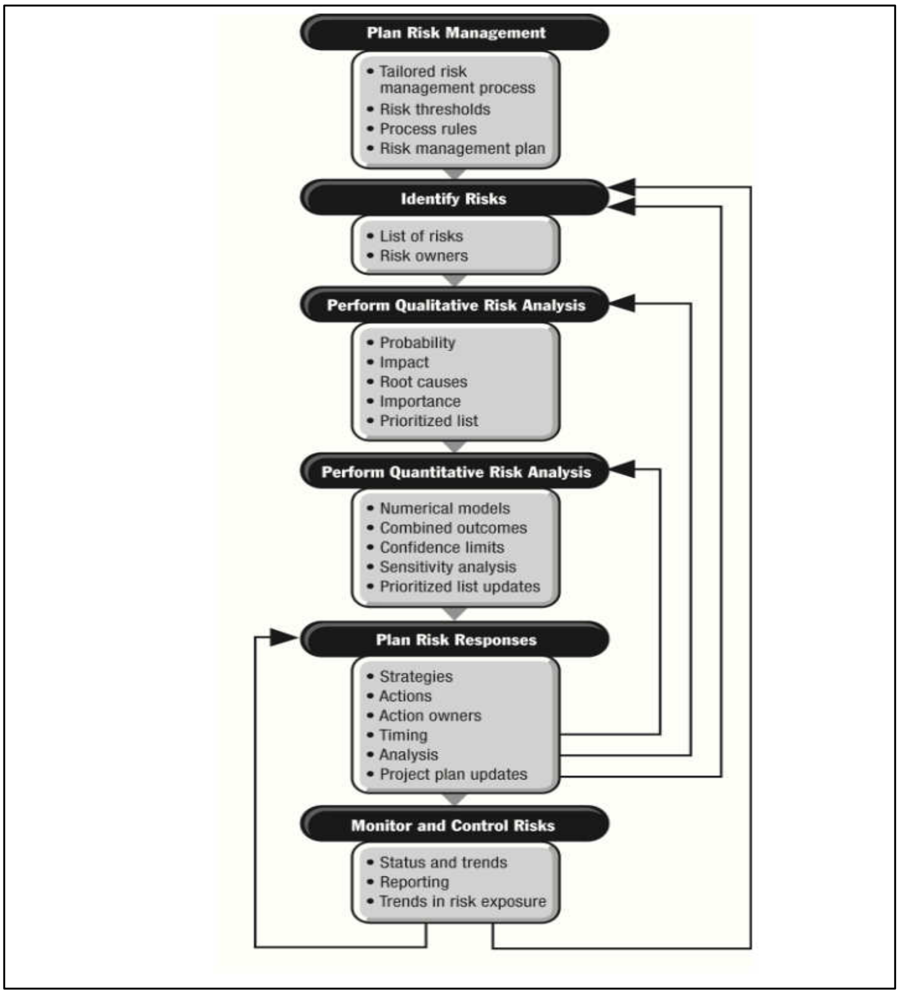

Figure 3: Project Risk Management Process Flow Diagram (PMI, 2009)

2.2. PROJECT RISK MANAGEMENT IN THE OIL AND GAS INDUSTRY

A number of sources have pointed out the importance of risk management and the continuous need for research and improvement on this topic in the oil and gas industry. For example, Cagianelli *et al*. (2015) introduced an Integrated Risk Management (IRM) model, stressing the importance of early project phases through planning and sufficient resource allocation as key success factors for oil and gas projects. Akinremi *et al*. (2015) emphasise the requirement for more sophisticated risk management models; they further developed a three-dimensional approach to sustainable projects (including investment, social and environment risks). They argue that this model is particularly relevant because many oil companies only focus on investment risks while ignoring the two other dimensions. Aven *et al*. (2007) have proposed a decision framework for risk management for offshore oil and gas projects; the framework consists of elements related to the decision-maker's vision, values and strategies, problem definitions and challenges, related stakeholder values, visions and long-term goals and the analyses of the consequences of each decision taken. Although the framework was developed for offshore oil and gas projects, the authors believe it is relevant to other domains.

Other scholars such as Kenzhetayeva *et al*. (2014) proposed a Risk Management Road Map (RMR). Their approach is based on past projects, especially in terms of the knowledge gained, so that traditional risk management practices are enhanced, especially in relation to the assessment and classification of different project risks. Avena and Pitblado (1998) discussed the tools relevant to safety management on the Norwegian and UK continental shelves. Their argument concentrated on the practices of risk analysis, risk communication and risk interpretation.

In the context of the MENA, particularly within the Gulf Cooperation Council, a recent study was done by Muralidhar (2010). The aim of this study was to investigate the practice of Enterprise Risk Management (ERM) among oil and gas companies. Muralidhar (2010) stressed that such a model is needed in the industry and concluded by recommending additional research on this newly recognized topic.

In to the case of Saudi Arabia, the oil and gas sector is fully controlled by Saudi Aramco, a fully state-owned company. The company recognises the importance of project risk management as a key integrated element with the company's overall strategy. The firm has recently established what they called 'Saudi Aramco Enterprise Risk Management', to guarantee that risk management processes are coordinated with the company's decision-making and planning processes (Aramco, 2013).

From the above discussion, it can be argued that project risk management is an important aspect of project management, ensuring the iterative identification and treatment of project risks (threats and opportunities), which could help in achieving a positive project outcome.

Having discussed the significance of project risk management and the importance of the oil and gas industry to the Libyan economy, the following sections will focus on the research methodology adopted for this study, followed by the discussion of its findings.

3. METHODOLOGICAL CONSIDERATIONS AND DATA ANALYSIS

This research project follows a single case study. Yin (2013) states that a case study is a relevant strategy when the researcher aims to obtain an in-depth and rich understanding of phenomena in their real-world context. The authors used the National Oil Corporation (NOC) of Libya as a single case, because the NOC is responsible for all the upstream (exploration and production) and downstream (refineries) aspects of the Libyan oil sector. Therefore, the NOC is considered to be a unique and important case.

To achieve the aim of this paper, semi-structured interviews were conducted with thirteen participants. This method was selected for primary data collection to arrive at a deep understanding of project risk management within the Libyan oil and gas industry, whereas other methods such as a questionnaire would not have been likely to achieve this. The flexibility of the interview format gave the authors the opportunity to ask further, more detailed questions when needed. The target population for this study was people who have direct experience with upstream projects in the Libyan oil and gas industry. Therefore, top managers, project managers, project engineers and project advisors made up the participant population for this study.

The interview respondents were asked about their understanding of the term 'risk', as well as concerning current project risk management practices, to capture the maturity and awareness of these practices within the organisation. Respondents were also asked about the challenges the Libyan industry is currently facing that limit the current project risk management practices.

Once gathered, interview data was transcribed and prepared for analysis. All transcripts were organised and coded, allowing the development of categories and the construction of emerging patterns, themes and subthemes. This process has helped the authors to generate the findings, discussion and conclusions for this paper, which will be discussed in more detail in the next two sections.

4. FINDINGS AND DISCUSSION

4.1. PERCEPTIONS OF "RISK"

Participants were asked about their understanding of the concept of 'risk'. The primary data revealed that the term was viewed differently among the participants. Interview respondents showed differing understandings of risk within the Libyan oil and gas industry. A majority of the participants perceived risk as representing an uncertain situation, a potential negative impact, or a threat that could affect the project or system. For instance, one participant defined risk as *'any obstruction or potential obstruction that limits achieving operational targets in a secure and safe manner'*. Another participant added that risk is *'anything that affects the system that eventually will lead to harm, whether this harm was financial or moral for the employees'*. This difference in the way that risk is perceived is in accordance with the academic literature; Haimes (2009) believed that although there is an enormous quantity of literature available to define risk and uncertainty, researchers and academic authors have not agreed on a common definition of either term. In addition, the topics of risk and risk management have been studied in numerous disciplines, which only adds to the confusion; there is therefore no clear or standardised definition of either term, and different understandings of the concepts can be found in the fields of economics, management, strategic management, and project management, among others (Ehsan, 2013).

While each participant thought of a risk as a threat, none of them defined it as an opportunity. According to the standard definition from the PMBOK, risk can be seen both as a threat and as an opportunity: *'Project risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope, schedule, cost and quality'* (PMI, 2013). Therefore, it is important to think of risk as representing possible opportunities as well, because such an opportunity could have a positive impact on the project, such as a decrease in material cost, which could lower the cost of the project.

4.2. PROJECT RISK MANAGEMENT MATURITY LEVEL WITHIN THE NOC

The interviews conducted for this research project generally indicated that maturity levels concerning project management and project risk management in the Libyan oil and gas industry lag behind international standards and procedures. This can be summarised by the comments made by one participant in particular: *'In Libya, and in the oil and gas industry, the culture and the understanding of the concept of project management is not available; if this concept is not presented, then I wouldn't be surprised about the lack of understanding of the topic of project risk management'*. When asked about the availability of a structured systematic approach to project risk management, all of those interviewed supported the claim articulated by one of the participants: *'I don't want to give you the impression that we have a systematic approach for management in general … we apply all of these on an "as it goes" basis. So as an approach or a system for project management or for project risk management in particular, believe me, it is not available!'* This finding is echoed in the literature; Sawalim (2015) spoke about his experience as a project manager in the NOC, arguing that the situation now is the same as it had been before the civil war. In addition, Sawalim (2015) claimed that current practices have not yet been developed, so managers still follow the old style of project management. As the oil and gas industry is a dynamic sector driven by technological change, one could argue that coping with such a fast-paced environment requires adherence to international project management procedures. The Libyan oil and gas industry fails to meet these standards.

4.3. CURRENT PROJECT RISK MANAGEMENT PRACTICES WITHIN THE NOC

As discussed previously (in subsection 4.2), no systematic approach is currently guiding project risk management practices within the Libyan oil and gas industry; some of those interviewed in this study have specified that although they do not follow a systematic written process, the practices recommended in project management literature are nevertheless applied. One of the interviewees indicated that: *'for many of our projects, we make sure to identify and assess any obstacles that affect the execution of the project or limit the completion rate; we take these issues into consideration and we address them, but we do not follow a systematic written approach'*. From another perspective, however, such an approach is used primarily to identify and assess risks that are related to health, safety and the environment, rather than other risk factors that might have a negative or positive impact on the project; this argument is supported by one of the participant's responses: '*it might be only in safety studies that we apply these practices'*.

According to the PMBOK (PMI, 2013), a structured project risk management process includes five procedures, 'e.g. project risk planning, project risk identification, project risk analysis (quantitative and qualitative), project risk response and project risk control'; however, it was clear from the results of this study that the NOC does not follow these steps, nor does it have a written policy or procedure to allow for the effective management of project risks. Instead, risk management practices have always been limited to the project manager or project engineer's knowledge and experience, rather than applying a systematic, documented approach: '*what I mean is: if you were an experienced project manager, you may have some feelings about what might affect the budget, schedule or quality, you find yourself (as a project manager) independently solving these issues on your own terms, without really applying a coherent approach …we do not have this at all'*. Therefore, identifying and assessing project risks within the Libyan oil and gas industry is mainly based on the efforts of project managers and their teams, without following a regulated framework that the organisation and the project manager can benefit from. However, the benefits of applying these practices have been well-documented in the literature; for example, de Carvalho and Rabechini (2015) and Firmenich (2017) have argued that applying project risk management practices have a positive influence on project success and have further emphasised the important role a risk manager can play in contributing to positive project outcomes. Therefore, ensuring the implementation of project risk management practices within the NOC can be expected to produce desirable results.

Although participants reported their belief that applying project risk management practices could improve project performance, the actual implementation of these practices remains challenging in the Libyan oil and gas industry. This might be rooted in the national or organisational culture of Libya; one of the respondents reflected that *'we are not using the science of risk management as part of the management of our projects; we are not using it at all, even our culture does not support this!'* (Liu *et al.*, 2015), offer support for this argument, claiming that project risks are viewed and managed differently among diverse national cultures. In their earlier research, Liu *et al*. (2013) showed that corporate culture influences project risk management. Meanwhile, Summerill *et al.* (2010), found that a proactive organisational culture could improve the project risk management process. Therefore, organisational culture could play an important role in the successful implementation of project risk management practices within the Libyan oil and gas industry. Creating the right organisational environment and increasing the awareness of project risk management within the NOC could enhance the successful delivery of its projects.

4.4. CHALLENGES LIMITING THE EFFECTIVENESS OF PROJECT RISK MANAGEMENT PRACTICES WITHIN THE LIBYAN OIL AND GAS INDUSTRY

Clearly, as a consequence of the unstable political and security situation in the country, the Libyan oil and gas industry is faced with many challenges that limit the development of formal and effective project risk management. The security situation does not only affect the safety of individuals; as one participant explained, *'The biggest challenge is the security situation of the country. This has led to the reality that good skilled labour, both Libyans and non-Libyans, have left the country. Also, we lost the participation of good international contractors; again, this is as a result of the country's security situation. The unstable political regime has a strong negative effect on our projects and our company; this has led to our budget being limited'*. Therefore, it can be argued that as a result of the country's situation, which led to financial constraints and the departure of many of skilled and experienced individuals, it became difficult for the NOC to manage its projects effectively and benefit from the application of project risk management practices because the company lacked the experienced workforce required. However, even before the Libyan revolution in 2011, when the country was more stable, the NOC already lacked a systematic project management approach to enable it to compete with other global oil and gas suppliers. Abouen *et al*. (2008) conducted a study before the Libyan revolution and found that strategic approaches regarding project management were largely absent in the Libyan oil and gas industry. Therefore, the challenges that limit the effective implementation of project risk management practices go beyond the current situation of the country, but (as discussed in subsection 4.3) are embedded within the strategic vision and the organisational and the national culture of the NOC.

5. CONCLUSIONS

This paper examined the current project risk management practices within the Libyan oil and gas industry. Project risk management is an important topic because it involves the quick identification, assessment, monitoring and controlling of events that might impact projects, negatively or positively. This paper provided an exploration into the current status of these practices specifically in the Libyan oil and gas industry. The findings from 13 interviews demonstrated that risk management literacy within the Libyan oil and gas industry is still very low. This paper also found that the Libyan industry lags behind the international standards for project management. Primary findings also show that there is typically no structured project risk management procedure in the NOC; rather, the application of these practices is limited to identifying and assessing risks that are related to health, safety and the environment; risk assessments in these areas are mainly based on the efforts and prior knowledge of project managers and their teams. Practitioners believe that applying formal project risk management practices could have a positive impact on project performance; however, practical implementation of these is challenging, according to participants, as a result of the current organisational and national culture of Libya. This paper also explored the effect of the country’s security and political situation on the oil and gas industry and summarised that this had and continues to have a negative impact not only on the safety of individuals but also on profitability and on the availability of experienced contractors and personnel; each of these factors limits the effectiveness of implementing a successful project risk management process. Thus, this paper concludes that project risk management is an important area of focus as it serves the rapid identification and assessment of project risk impacts and thereby sets in motion the measures required to monitor and control these impacts; therefore, it should become a priority in the Libyan oil and gas industry as the country and the industry undergo many challenging risks.

6. REFERENCES

Abouen, S., Ahmed, V. and Aouad, G. 2008. *Project manager development in the Libyan oil Industry* [Online]. Available from: http://www.irbnet.de/daten/iconda/CIB16751.pdf [Accessed 10 March 2017].

Ajah, E.G. 2014. *OPEC as a cartel: The influence of its policy on the global oil market* [Online]. Available from:http://www.academia.edu/29032598/OPEC_AS_A_CARTEL_THE_INFLUENCE_OF_ITS_POLICY_ON_THE_GLOBAL_OIL_MARKET [Accessed 7 March 2017].

Akinremi, T., Anderson, R., Olomolaiye, A. and Adigun, L. Risk management as an essential tool for successful project execution in the upstream oil industry. *Abu Dhabi International Petroleum Exhibition and Conference*, 2015. Abu Dhabi, Society of Petroleum Engineers.

Al Subaih, A. 2015. Integrated project delivery: A paradigm shift for oil and gas projects in the UAE and the Middle East region. *Oil and Gas Facilities,* 4**,** 64-77.

Aramco, S. 2013. *2013 Annual review: Our strategy* [Online]. Saudi Aramco. Available from: http://www.saudiaramco.com/content/dam/Publications/annual-review/2013/2013AR_Our_Strategy.pdf [Accessed 23 Jan 2017].

Aven, Vinnem, J.E. and Wiencke, H.S. 2007. A decision framework for risk management, with application to the offshore oil and gas industry. *Reliability Engineering and System Safety,* 92**,** 433-448.

Avena, T. and Pitblado, R. 1998. On risk assessment in the petroleum activities on the Norwegian and UK continental shelves. *Reliability Engineering and System Safety,* 61**,** 21-29.

Badiru, A.B. and Osisanya, S.O. 2013. *Project Management for the Oil and Gas Industry: A World System Approach.* London, CRC Press.

Benta, D., Podean, M. and Mircean, C. 2011. On best practices for risk management in complex projects. *Informatica Economica Journal*, 15**,** 142-152.

Besner, C. and Hobbs, B. 2012. The paradox of risk management; a project management practice perspective. *International Journal of Managing Projects in Business,* 5**,** 230-247.

BP. 2016. *Energy Outlook: Outlook to 2035* [Online]. London, United Kingdom: BP. Available from: https://www.bp.com/content/dam/bp/pdf/energy-economics/energy-outlook-2016/bp-energy-outlook-2016.pdf [Accessed 4 March 2017].

Briel, E., Luan, P. and Westney, R. 2013. Built-in bias jeopardizes project success. *Oil and Gas Facilities*, 2, 20-23.

Brown, D. 2014. *Africa's Booming Oil and Natural Gas Exploration and Production: National Security Implications for the United States and China*. CreateSpace Independent Publishing Platform.

Burtonshaw-Gunn, S.A. 2009. *Risk and Financial Management in Construction*. Surrey: Gower Publishing, Ltd.

Cagianelli, M., Michelez, J. and Nava, F. 2015. Integrated risk management to meet the challenges of today's oil and gas industry. *Offshore Mediterranean Conference.* Ravenna, Italy: Offshore Mediterranean Conference.

Dayanandan, A. and Donker, H. 2011. Oil prices and accounting profits of oil and gas companies. *International Review of Financial Analysis,* 20**,** 252-257.

De Carvalho, M.M. and Rabechini, R. 2015. Impact of risk management on project performance: The importance of soft skills. *International Journal of Production Research,* 53**,** 321-340.

Deloitte 2015. *Oil and Gas Reality Check 2015: A look at the top issues facing the oil and gas sector*. London: Deloitte.

Ehsan, E. 2013. Risk management: The next source of competitive advantage. *Foresight,* 15**,** 117-131.

EIA. 2015. *Country Analysis Brief: Libya* [Online]. U.S Energy Information Administration. Available from: https://www.eia.gov/beta/international/analysis.cfm?iso=LBY [Accessed 1 March 2017].

EY 2014. *Spotlight on Oil and Gas Megaprojects.* London: Ernst and Young Global Limited.

EY 2015. *Joint Ventures for Oil and Gas Megaprojects.* London: Ernst and Young Global Limited.

Firmenich, J. 2017. Customisable framework for project risk management. *Construction Innovation,* 17**,** 68-89.

Haimes, Y.Y. 2009. On the complex definition of risk: A systems-based approach. *Risk Analysis,* 29**,** 1647-1654.

IEA. 2015. *World Energy Outlook 2015* [Online]. France: International Energy Agency. Available: http://www.worldenergyoutlook.org/media/weowebsite/2015/WEO2015_Factsheets.pdf [Accessed 28 Feb 2017].

Inkpen, A.C. and Moffett, M.H. 2011. *The Global Oil and Gas Industry: Management, Strategy and Finance.* Tulsa: PennWell Books.

Kenzhetayeva, Z., Ribeiro, M.T., Oliveira, N., Carvalho, L. and Bicho, M. 2014. A risk management roadmap for capital oil and gas projects. *Abu Dhabi International Petroleum Exhibition and Conference.* Abu Dhabi, UAE: Society of Petroleum Engineers.

Liu, J., Meng, F. and Fellows, R. 2015. An exploratory study of understanding project risk management from the perspective of national culture. *International Journal of Project Management,* 33**,** 564-575.

Liu, J., Zou, P.X.W. and Gong, W. 2013. Managing project risk at the enterprise level: Exploratory case studies in China. *Journal of Construction Engineering and Management,* 139**,** 1268-1274.

Miyoshi, M. 1999. The joint development of offshore oil and gas in relation to maritime boundary delimitation. *Maritime Briefing* 2(5). Durham: International Boundaries Research Unit.

Muralidhar, K. 2010. Enterprise risk management in the Middle East oil industry: An empirical investigation across GCC countries. *International Journal of Energy Sector Management,* 4**,** 59-86.

Otman, W. and Karlberg, E. 2007. *The Libyan Economy: Economic Diversification and International Repositioning.* New York: Springer Science and Business Media.

PMI 2009. *Practice Standard for Project Risk Management.* Pennsylvania, Project Management Institute, Inc.

PMI 2013. *A Guide to the Project Management Body of Knowledge (PMBOK Guide).* Newtown Square, Pennsylvania: Project Management Institute.

Rabechini, R. and De Carvalho, M. 2013. Understanding the impact of project risk management on project performance: An empirical study. *Journal of technology management and innovation,* 8**,** 64-78.

Rogers, V.C. and Ethridge, J.R. 2013. Enterprise risk management in the oil and gas industry: An analysis of selected Fortune 500 oil and gas companies' reaction in 2009 and 2010. *American Journal of Business Education,* 6**,** 577.

Salazar-Aramayo, J.L., Rodrigues-Da-Silveira, R., Rodrigues-De-Almeida, M. and De Castro-Dantas, T.N. 2013. A conceptual model for project management of exploration and production in the oil and gas industry: The case of a Brazilian company. *International Journal of Project Management,* 31**,** 589-601.

Sawalim, K.M.H. 2015. *Appraising project performance and Total Quality Management (TQM) practices in the Libyan oil and gas sector.* PhD, Liverpool John Moores University.

Summerill, C., Pollard, S.J.T. and Smith, J.A. 2010. The role of organizational culture and leadership in water safety plan implementation for improved risk management. *Science of the Total Environment,* 408**,** 4319-4327.

Thamhain, H. 2013. Managing risks in complex projects. *Project Management Journal,* 44**,** 20-35.

Yin, R.K. 2013. *Case Study Research: Design and Methods.* California: Sage publications.

Zwikael and Ahn, M. 2011. The effectiveness of risk management: An analysis of project risk planning across industries and countries. *Risk Analysis,* 31**,** 25-37.

INVESTIGATION INTO WORKPLACE HEALTH AND SAFETY ISSUES WITHIN THE AUSTRALIAN COMMERCIAL CONSTRUCTION INDUSTRY'S MIGRANT WORKFORCE

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ABSTRACT

Each year, there are approximately 12,600 workers compensation claims arising from the Australian construction industry, each representing an injury or health condition resulting in loss of productivity. In 2013–14, the construction industry accounted for around 9% of the Australian workforce, but accounted for overall 12% of workplace related fatalities. Previous studies have shown a high association between accident rates in the construction industry and the migrant workforce adversely impacting on social sustainability. The main issues faced by non-English speaking workers were language, cultural barriers, training barriers and communication. The migrant workforce is equivalent to roughly 24% of the construction industry's total workforce. Over 11% of workers originate from countries where English is the first language and 12.2% originate from non-English speaking countries. The aim of this study is to investigate the challenges faced by non-English speaking migrant workers including communication and cultural barriers, and to explore any potential impacts this may have on construction site safety as a key contributor in achieving social sustainability. It presents a detailed single case study that is representative of a typical case, a typical "project" among many different projects. Data is captured on everyday working conditions using a series of tripartite interviews (project managers, site managers and Workplace Health and Safety officers). Using the triangulation theory, multiple perspectives were sought instead of looking only from a single perspective to facilitate a deeper understanding of these issues. The research found many unsafe working practices endemic to migrant workers and that communication and language barriers faced by migrant workers have an adverse impact on site safety within the Australian commercial construction industry.

Keywords: *Australia; Construction Safety; Migrant Workers; Workplace Health and Safety (WH&S).*

1. INTRODUCTION

1.1. BACKGROUND OF WORKPLACE HEALTH AND SAFETY

According to Safe Work Australia (2016), up to 1.01 million people were employed in the Construction industry during 2011-2012 in Australia. This accounts for approximately 9% of the Australian workforce for the 2011-2012 period. In New South Wales, 260,800 people were employed in the construction industry during the same period. The construction industry is vital to Australia's economy, and is a major contributor to the growth of Australia's economy (The Australian Bureau of Statistics, 2016). One of the major Australian building and construction industry associations, Master Builders Australia, considers the building and construction industry to be a key driver of the Australian economy, making a major contribution to the generation of wealth and the welfare of the community, particularly through the provision of shelter (Master

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Builders Australia, 2016). According to the Australian Bureau of Statistics (2016), the construction industry is crucial to Australia's economic growth, with 7.7% contribution (in 2015) and as the 4th largest contributor to Australia's gross domestic product (GDP). To ensure Australia's construction industry stays strong, it is vital that a set of rules and regulations are put in place to ensure a safe workplace. Workplace health and safety in Australia has been ranked among the best safety standards in the world (Safe Work Australia, 2016). The construction industry workforce has increased by 33% over the past decade (The Australian Bureau of Statistics, 2016). Employees account for 76% of the construction industry workforce in Australia, and each employee is covered by workers' compensation insurance (Safe Work Australia, 2016). Over the last 10 years, a significant reduction in the number of fatalities and injuries have been reported for the construction industry as per Table 1, however it still remains a high risk industry to work in.

Table 1: Worker Fatalities in the Construction Industry

	No. of fatalities		Fatality rate		
Industry sector	**2003–07**	**2009–13**	**2003–07**	**2009–13**	**% chg**
Construction services	**138**	**119**	**4.69**	**3.38**	**-28%**
Building installation services	44	43	4.75	3.42	-28%
Land development & site preparation services	34	28	15.32	9.94	-35%
Building completion services	13	22	1.43	2.20	54%
Building structure services	30	13	6.67	2.73	-59%
Other construction services	17	13	3.96	2.59	-35%
Building construction	**20**	**21**	**1.89**	**1.76**	**-7%**
Heavy & civil engineering construction	**38**	**27**	**13.76**	**7.35**	**-47%**
Total	**196**	**167**	**4.59**	**3.29**	**-28%**

(Source: Safe Work Australia, 2016).

Nine percent of the Australian workforce comprised of workers in the construction industry during 2011-2012, however it accounted for approximately 10% of workers compensation claims involving more than a week out of work during the same period (Safe Work Australia, 2016). Each year, there are approximately 12,600 workers compensation claims from the construction industry alone, each representing an injury or health condition that involves taking one week or more off work. This works out to be approximately 35 major claims a day. During the 2012 - 13 period, the construction industry was ranked 4th highest for rates of serious claims per 1000 employees (Safe Work Australia, 2016). During the 2013 - 14 period, workers in the construction industry comprised the same percentage of the Australian workforce, however 12% of workplace fatalities came from the construction sector (Safe Work Australia, 2016). When analysed for fatality rate per 100,000 employees, the industry was ranked 5th highest during the 2013 - 14 period (Work Cover Authority, 2016). Occupational injuries, deaths and illnesses place an extra financial burden, both direct and indirect, on workers, employers and the community. For example, direct costs include workers compensation premiums paid by employers, or payments to workers injured on-site or whilst travelling to and from work. Indirect costs are more difficult to calculate because they encompass factors such as lost earnings (both present and future), lost productivity, lost output and so forth. The extent of this financial burden may vary, depending on the severity of the injury or health condition (Johns 2012). Direct costs are more measurable; however these costs cover only a fraction of the total cost of work-related injury and disease. According to Safe Work Australia (2016) for the period 2009 - 2010, $7.3 billion was paid to workers compensation schemes. These payments consisted of: i) $4.06 billion in direct payments (permanent impairment, incapacitated) (55.7%), ii) $1.63 billion paid to medical, rehabilitation and other services (22.4%), iii) $1.27 billion paid to insurance operations costs (17.4%) and iv) $332 million paid to other administrative costs (4.6%).

1.2. PROBLEM STATEMENT

Many industries aim to minimise costs in order to maximise profits (ILO, 2012). A factor in minimising cost in the construction industry involves outsourcing physical work to sub-contractors (ILO, 2012). This practice in turn extends the division of labour. One key dynamic of this division of labour has been subcontractors hiring migrant workforces to try and obtain key skill requirements and reduce total labour costs (ILO, 2012).

Previous studies have made associations with high accident rates in the construction industry and the migrant workforce (Trajkovski and Loosemore, 2006; Loosemore and Andonakis, 2007; Salleh *et al*., 2012). The migrant workforce is equivalent to roughly 24% of the construction industry's total workforce. Over 11% of workers originate from countries where English is the first language and 12.2% originate from non-English speaking countries (Australian Bureau of Statistics 2016). A large number of workers have been identified as illegal immigrants working within in the industry. This presents yet another challenge for construction sites in Australia. The figures above do not include illegal immigrant statistics (Wallace, 2011).

A mixture of cultural and communicative barriers among non-English speaking workers may create detrimental impact on quality and safety standards within the commercial construction industry. Literature has shown a link between the deterioration of safety and quality standards and an increasing migrant-dominated workforce (Loosemore and Lee, 2002, Skilled Migration Survey, 2011; Rosewarne *et al*., 2012; Department of Immigration and Border Protection, 2016). The aim of this study is to explore this issue further and expand on previous research, and to identify factors that contribute to this effect.

1.3. Research Significance

Problems relating to non-English speaking migrant workers in the construction industry have been examined previously in other studies including Loosemore and Andonakis, 2007, Allen, 1976, Premji *et al*., 2008, Loosemore and Lee, 2002, Trajkovski and Loosemore, 2006 and Salleh *et al*., 2012). The previous research undertaken in this area has helped to build knowledge about various issues faced by this section of the workforce. The outcomes of this previous research demonstrated the main issues faced are language, cultural barriers, training barriers, communication. Therefore, strategies aimed at addressing these issues are likely to have a positive impact on workplace health and safety issues relating to the migrant workforce. If these quality and safety issues are left unaddressed, this may result in negative outcomes such as accidents, delayed work, loss of productivity, insurance expenses, injuries, fatalities, disabilities. It is vital for managers to fully understand the problems that non-English speaking (NES) workers face, and to help resolve the issues as quickly as possible. These issues mentioned above will be investigated in this study, to help understand the issues faced by these migrant workers and the potential dangers they may present to the commercial construction industry.

1.4. Research Aim and Objectives

The aim of this research is to investigate issues faced by migrant workers working on construction sites. The specific objectives of the research includes: (i) Investigate migrant trends that specifically relate to the subcontractor trades of tiling, plastering and painting; (ii) Examine the communication barriers faced by the migrant workforce and explore how these different barriers can affect quality and safety standards in the commercial construction industry. (iii) Explore the different communication, language and training barriers which exist between construction workers with English speaking background and the migrant workforce with non-English speaking background, and (iv) Investigate cases involving migrant workers and assess what was learned from those experiences. The research reported in this paper has been carried out within the New South Wales construction industry on a Tier 2 construction company representing the Australian commercial construction industry. The research therefore is based on a single a case study. Within the case study, data triangulation theory was applied by conducting a formal interviews with three categories of stakeholders. These categories include safety officers, site supervisors and project managers. Key terms used in this paper are; Migrant Workers and Non English Speaking Migrant Workers (NESMW). A migrant worker is a worker that comes to work in Australian from overseas. Migrant workers remain classed a migrant worker until they become permanent resident or Australian citizens and Non-English speaking migrant workers (NESMW) is a worker who cannot speak English and comes from a country that has a first language other than English.

2. Multiculturalism / Diversity in the Australian Construction Industry

The construction industry is ideally suited to take advantage of cultural diversity. Diversity is defined as a very broad term, it recognises a variety of characteristics that make individuals unique. These include differences in age, cognitive thoughts, disability, culture, language, gender identity, ethnicity, education, marital status, economic background, geographic background, religious beliefs, race, appearance, sexual orientation and the like (University of Tennessee, 2012). Multiculturalism is an ever increasing feature of Australia’s construction industry. When different cultures intermix, opportunities are created for other cultures to communicate with each other and work together to create a multicultural environment. Australia has a multicultural society and promotes a multicultural policy that provides fairness, equality, and inclusion for everyone. Australia supports a wide variety of religious, cultural and linguistic diversity, shared values and cultural traditions with the law and free from discrimination (Department of Immigration and Border protection, 2016). Therefore, construction sites must operate under the same set of laws and principles as the rest of Australia. For the period 2014-2015, 168,200 persons migrated to Australia under a number of classifications including skill migration, family migration, special eligibility and humanitarian. According to the Department of Immigration and Border Protection (2016), the top 5 nationalities who migrated to Australia in 1949 were from Italian, German, Polish Yugoslav and Greek background.

During the 2011-2012 period, 84,183 people became Australian citizens from one hundred and eighty different countries. Table 2 shows the breakdown of Australian citizenship during the 2011-2012 period, listing them by country of origin.

Table 2: Australian Citizenship Breakdown 2011-2012 (Source: Mantoufeh, 2012)

Former Citizenship	**Persons**	**(%)**
United Kingdom	16401	19.5
India	10076	12.0
People’s Republic of China	6876	8.2
Philippines	5592	6.6
South Africa	4206	5.0
New Zealand	3458	4.1
Vietnam	1929	2.3
Sri Lanka	1671	2.0
Republic of South Korea	1570	1.9
Malaysia	1487	1.8
Other	30917	36.7
Total	84183	100.0

KPMG’s study on Australian skilled migration identifies migrant workers as becoming more viable and an alternative to fill labour shortages within Australia’s construction industry. Australian temporary work visa previously known as the 457 visa allows businesses to employ skilled workers outside of Australia to come and work within Australia. This may bring sponsored skilled workers to the construction industry. Skills include painting, tiling, plastering, carpentry etc. (Department of Immigration and Border Protection, 2016). The temporary work visa shows an increase of skilled workers most prominent in the construction, mining, and manufacturing industries. 10 percent of the temporary work visa workers gain work within the construction industry. The highest source regions for skilled migrant comes from the United Kingdom. The rest of Europe (17.5%) and China/South East Asia (15.5%). To summarize, the Australian construction industry is a multicultural environment which has led to several areas of concern especially for working trades that have a high percentage of NESB workers. The biggest multicultural barrier faced by the industry is language, but the existence of illegal migrants within the industry is also of significant concern as it directly affects safety, economy, and safety and work quality.

2.1. MIGRANTS SPECIFIC TO TRADES

According to Mantoufeh (2012) reducing costs to increase profit margins in the Australian construction industry has led to construction firms concentrating on contracting and project management and leaving the physical work to subcontractors. The consequence of this has led to numerous subcontractors employing migrant workers. By hiring migrant workers, these sub-contractors can reduce labour costs and source its necessary skill requirements.

There are many trades within the construction industry that do not require any formal qualifications e.g. Painting. A common strategy within Australia construction industry has been for licenced contractors to hire migrant workers in trades that do not require qualifications. According to Constance and Quinland (1988) this is no new occurrence, Italian immigrants arriving to Australia post World War 2, relied on their experience rather than on qualification. These Italian migrant workers used their experience to dominate the tiling, concreting and rendering trades. In more recent times, the majority of migrants coming to Australia are coming from countries within Asia such as India and China. These workers are being drawn to the same trades as the Italian migrants before them. These new migrants have a tendency to work in the trades of painting, plastering, cleaning and tiling (Rosewarne *et al.*, 2012; Mantoufeh, 2012; Loosemore and Lee, 2002; Department of Immigration and Border Protection, 2016). New migrants are being drawn to these trades because there is no formal qualification needed to work in these trades. There is evidence to suggest that a large number of temporary migrants are being drawn into certain occupations within Australia’s construction Industry. Work in these occupations is often on an irregular and casual arrangement and usually take the form of non-standard agreements. In many of these cases, workers are paid cash in hand, which allows the workers to avoid paying tax on their earnings and employers to are able to avoid paying superannuation, payroll tax and standard industry wages requirements including workers compensation insurance. This is supported by Rosewarne *et al.* (2012) and Mantoufeh (2012), who state that conditions are generally irregular and against legislation and enterprise agreements.

There is very little research into the cash economy of undocumented workers. Due to the lack of research it is impossible to estimate how much these workers are costing the Australian economy each year. Shin (2010) conducted research on Korean and Chinese nationals working in Sydney’s metropolitan areas tiling sector. The research specifically focused on the standard forms of work and its prevalence within the sector. Shins research determined that by employing migrant workers on temporary and residence visas, as well as hiring undocumented workers, subcontractors have been able to reduce costs by paying cash to evade paying tax, paying workers less than their legal entitlements, not paying workers compensation insurance and by not paying workers superannuation. Migrant workers coming to Australia need to have appropriate training and language assistance provided to them. Without this training and language assistance, many of these workers present serious WH&S concerns which may have serious implications for site safety within Australia. These migrant workers are being placed in exceptionally vulnerable positions as not only are they not being provided with adequate training, there is no protection being provided by the subcontractors they work for. This includes failing to pay workers compensation, which by itself is a serious concern.

2.2. COMMUNICATION

All human languages are tools aiming to solve the problem of communication (Everett, 2012). For migrant workers living in host societies, communication can be difficult due to workers being from different regions, socio economic backgrounds, speaking different languages, levels of education and training. This can lead to migrant workers being marginalized and excluded socially from their host society. Migrant workers who experience communication barriers, such as speaking limited English, are susceptible to health and safety issues (Lo, 2014).

Proper communication is essential for a workplace to operate effectively and safety. This is especially true for the communication between an English speaking workforce and a non-English speaking workforce. The dominant language on Australian construction sites is English. Workplaces are the most likely context in which a non-English speaking worker will need to use English (Clyne and Ball, 1990).

Australian workplaces, can be difficult to navigate for migrant workers as English language and literacy skills are required. While workers may be proficient in their native tongue for everyday speaking and writing tasks, they lacked this proficiency in English for similar tasks. This meant they were unable to participate and understand fully the requirements of the workplace environment where English is dominant (Mantoufeh, 2012).

Proficiency in the official language can influence WH&S by impacting on the workers ability to understand and communicate information and supported relationships that can affect work related health. Language proficiency refers to the worker’s ability to understand and be understood both orally and in writing (Mantoufeh, 2012). It is imperative that cultural and communication barriers are overcome to prevent difficulties arising in the workplace. Statistics indicate that multiculturalism is an ever increasing feature of the Australian construction industry. The result of having a diverse workforce can generate significant challenges. The consequences of mismanaging these challenges and cultural groups can create frustration, stress, confusion and conflict within the workplace. This leads to lower morale, productivity, quality problems and increase in accident rates (Mantoufeh, 2012). It is apparent a culturally diverse workforce will remain a prominent feature of the Australian construction industry into the foreseeable future and that it is a challenge that managers will need to overcome well into the future. To prevent difficulties arising managers should have an understanding of the different cultures in their workplace. To do this, managers can familiarise themselves with the body language and customs of the workers. This will help in understanding the different communication styles of each culture, which can reduce the chance of misinterpretation. This is supported by Vandenheuvel and Wooden (1997) who suggests that management need to understand the cultural differences between workers and help to create cohesion between all cultures on site by providing English training for non-English speakers. This creates less reliance on information being spread by informal methods of literacy (Beal, 1990; Lo, 2014). If issues' surrounding migrant workers is not tackled by management, non-English speaking workers, will begin to rely more on other non-English speaking workers for information on regarding their safe work practices. This is important for two reasons. Firstly, this means accessing information remain under the control of the worker. Information needs to be clearly distinguished from any formal and informal attempt to convey workplace health and safety information (Trajkovski and Loosemore, 2006). Secondly, this is not adequate safety training and workers need to be taught based on their level of literacy (Beal, 1990). Mantoufeh (2012) suggests that the use of graphic images showing basic safety messages can be useful. However Lo (2014) suggests that even if health and safety documents are translated into their native language, those workers with limited English may be at risk of unexpected dangers if they cannot fully understand verbal instructions or danger warnings. Mantoufeh (2012) has suggested the use of specialist safety advocates, who are able to communicate with a bilingual workforce in order to relay information to workers.

3. RESEARCH METHODOLOGY

The research method chosen for this paper is a single case study design, which is made up of individual observations and data collected in interviews, and via a Likert scale questionnaire. The reason a single case design was used is that a single case study design is the representative of a typical case. The object is to try and capture everyday conditions and circumstances. The case study may represent a typical "project" among many different projects (Yin, 2009). The data collection methods used in this case study have been have been established by reviewing the supporting literature and in consultation with Western Sydney University academics. For the case study, the triangulation theory was used to obtain a more precise picture of WH&S in relation to NESMWs at the commercial construction company. According to the triangulation theory, multiple perspectives of the same phenomena may enable a more precise picture to be developed, in comparison to results gained from only one perspective. This is achieved through a triangulation of observers where many different people observe the same phenomenon (Neuman, 2011 and Yin, 2009). In this study, the triangulation theory has been used to get insights from a range of construction personnel, who gained knowledge on the issue of WH&S through their experience in their particular roles and duties (Neuman, 2011). Qualitative data collection methods were used to obtain data through interviews and a questionnaires. The responses are then triangulated by looking at those that are agreed upon by the participants (Guion *et al,* 2002). This approach helps to enhance the validity of the findings by using different sources of information to investigate the research question, to increase confidence that the findings reflect the true situation at the company (Guion *et al*., 2002). This interview questions and questionnaire materials were subjected to stringent Western Sydney University ethics approval. After a series of amendments, the interview questions were granted ethics approval. Three categories of people were interviewed from three different positions namely, Site Supervisors, WHS officer and Project Manager within the chosen commercial construction company that deal directly with matters relating to site safety. Based on their comments and experiences with site safety relating to NESMW results were compiled to form the representative typical case, or 'project' among other projects, in the commercial construction industry for theory building purposes. Participants employed in these positions were selected due to their broad understanding of WH&S concerns and practices on commercial construction sites, to provide insight into potential issues relating to NESMW. Furthermore, their positions include dealing with WH&S issues on a daily basis and usually involve experience of working with NESMW. A total of 9 interviews were conducted for each of the three categories. All interview participants are from the same tier 2 commercial construction company.

4. RESEARCH FINDINGS AND CONCLUSIONS

The results of this study have shown the Australian commercial construction industry to be a very multicultural industry. Due to the commercial construction workforce being so culturally diverse, problems become apparent. This case study found communication to be a major problem faced by the non-English speaking migrant workforce within the commercial construction industry. These communication issues may have adverse effects on site safety within the Australian commercial construction industry. The language barriers faced by non-English speaking migrant workers investigated in this study have revealed problems with communication on safety requirements, safe work instruction, safety training and site inductions. This is consistent with the findings of previous studies (Mantoufeh, 2012; Saleh *et al.*, 2012; Trajkovski and Loosemore, 2006).

Further problems were found during this study. These problems included the workers continuing to resort to work practices and cultural norms from their home country. Workers did not conform to site safety requirements by not using the correct Personal Protective Equipment (PPE), having untagged tools and by conducting unsafe work practices. There were several reports of non-compliant work and miscommunication. Various Construction personnel have stated that while dealing with non-English speaking migrant workers they have faced stress, frustration and confusion when communicating with non-English speaking migrant workers. This study has found that despite the communication barriers that exist with NESMW, employers continue to hire them to reduce labour costs and fulfil their skills needs. Construction managers have yet to establish an efficient way of communicating and dealing with the NESMW. Often NESMW have been reported to use third party communication methods and documentation to aid in understanding the language barriers. This informal method of communicating safety instructions may have adverse effects on site safety as the information being passed on through these channels may be incorrect or misinterpreted.

The findings suggest there is deterioration in safety and quality assurance within certain trades in the commercial construction industry. Particularly in the plastering, cleaning and tiling trades. Additionally, the findings of this study have recognized the use of new technology to aid in overcoming the language and communication barriers, e.g. Google translate. Finally the results of this study have established that the commercial construction industry is a multicultural industry. The three chosen subcontractor trades of plastering, tiling, and final clean were identified to up to 70% NESMW. This is further supported by the interviews carried out on WH&S officers, site supervisors and project managers. Both communicative and cultural barriers were found to be present within the commercial construction industry. These communicative and cultural barriers have caused deterioration in safety standards. Interestingly despite the findings of some studies mentioned in the literature review of this study, communicative and cultural barriers were not found by interview participants to have detrimental effect quality standards.

The findings of this study had shown that there are many different communications, language and training barriers exist between construction workers and the NESM workforce. These barriers were found to be detrimental to site safety but not to work quality.

It was also found that while management do aim to resolve and eliminate the negative effects created by these barriers, there is little or no special attention given to needs of NESMW in regards to site safety. Interview respondents reported that there was no special or additional safety training provided to NESMW to ensure that they fully understand site safety. This may be detrimental to safety on site.

The interview participants reported a wide range of real experiences of dealing with NESMW. There was many cases of unsafe work practices, communication problems, and misunderstandings, cultural norms, stress and frustration. However interview participants reported NESMW to be hard working with the capability to work fast in large teams. During this research, considerable challenges were found to be facing NESMW with regards to safety and quality assurance on Australian construction sites. Different cultural and communicative barriers have created these considerable challenges. It can be concluded that communication and language barriers faced by NESMW have an adverse impact on site safety within the Australian commercial construction industry.

5. REFERENCES

Beal, C., 1990. It's all in the Asking A Perspective on Problems of Cross Cultural Communication Between Native Speakers of French and Native Speakers of Australian English in the Workplace. *Australian Review of Applied Linguistics*. 7, 26-32.

Clyne, M. and Ball, M. 1990. English as a Lingua Franca In Australia Especially in Industry: a First Report. *Australian Review of Applied Linguistics*. 7, 1-15

Constance, L. T. and Quinland, M. 1988. *A Divided Working Class*. London United Kingdom: Routledge & Kegan Paul.

Department of Immigration and Border Protection, 2016. *Australian Citizenship Statistics*. [online]. Available from: https://www.border.gov.au/Trav/Citi/Lear/Facts-and-statistics [Accessed 4 April 2016].

Everett D., 2012. *Language: the Culture Tool*. UK: Profile Book Ltd.

Guion L.A., Diehl D.C. and McDonald D., 2013. *Triangulation: Establishing the Validity of Qualitative Studies*. [online] Available from: https://edis.ifas.ufl.edu/fy394 [Accessed 14 April 2016].

International Labour Organisation (ILO), 2012. *The enormous burden of poor working conditions*. Available from: http://www.ilo.org/moscow/areas-of-work/occupational-safety-and-health/WCMS_249278/lang--en/index.htm [Accessed 10 April 2016]

Lo, L. 2014. The Role of Language and Communication for the Migrant Community Integration into Host Society: A Case Study on the Chinese Community in UK, GSTF. *International Journal of Law and Social Sciences* (JLSS), 3(2), 46-51.

Loosemore, M. and Andonakis, N., 2007. Barriers to implementing OHS reform the experiences of small subcontractors in the Australian construction industry. *International Journal of Project Management*, 25(6), 579-588.

Loosemore, M. and Lee, P., 2002. Communication Problems with Ethnic Minorities in the Construction Industry, *International Journal of Project Management*, 20(7), 517-524.

Master Builders Australia, 2016. *Economics.* [online]. Available from: http://www.masterbuilders.com.au/portfolios/economics. [Accessed 13 May 2016].

Mantoufeh, A., 2012. *Investigation into WH&S Issues within the Australian Residential Construction Industries Migrant Workforce*, B Construction Management Thesis, Western Sydney University, Australia.

Neuman, W.L., 2011. *Social Research Methods: Qualitative and Quantitative Approaches*. 7th ed. Boston: Allyn and Bacon.

Rosewarne, S., Shin, J.S., McGrath-Champ, S. and Toner, P. 2012. *The Globalisation of The Construction Workforce, A Report on The Impact on the Australian Building and Construction Industry*, Sydney University, pp. 1-17.

Safe Work Australia, 2016. *Work-related injuries and fatalities in construction, Australia, 2003-2013*, [online] Available from: http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/fatalities-in-construction. [Accessed 16 May 2016].

Salleh, N.A.B., Nordin, N.B.M. and Rashid, A.K.B.A., 2012, 'The Language Problem among Foreign Workers in the Malaysian Construction Industry. *International Journal of Business and Social Science*, 3(11), 97-99.

Shin, J.S., 2010. Korean Tiling Workers' Informal Skill Formation and Role of Division of Labour in the Sydney Construction Industry. In *28th International Labour Process Conference*, USA, 15-17 March 2010. New Jersey, 1-13.

Skilled Migration Survey, 2011. *KPMG*, [online] Available from: http://murraynow.com.au/static/files/assets/5c1eff8f/skilled- migration-survey-2011.pdf [Accessed 3 February 2013].

The Australian Bureau of Statistics, 2016. *2014-15 Key Industry Figures*. [online] Available from: http://www.abs.gov.au/ausstats/abs@.nsf/0/48791677FF5B2814CA256A1D0001FECD?Opendocument [Accessed 13th May 2016].

Trajkovski, S, and Loosemore, M., 2006. Safety implications of low English proficiency among migrant construction site operatives. *International Journal of Project Management*, 24(5), 446-452.

University of Tennessee, 2012. *What is Diversity*. [online] Available from: http://www.lib.utk.edu/diversity/diversity_definition.html [Accessed 8 May 2016].

Vandenheuvel, A. and Wooden, M. 1997. Immigrants; Training; Employment; Non-English-Speaking-Background. *Ethnic and Racial Studies*, 20(4), 830-848.

Wallace, N., 2011. *Illegal Workers Rife in Construction Industry, Union Claims. Sydney Morning Herald.* [online] Available from: http://www.smh.com.au/nsw/illegal-workers-rife-in-construction-industry-union-claims-20110724-1hvgo.html#ixzz2K0Jt8Dah [Accessed 04 February 2013].

Work Cover Authority NSW, 2016. *Definitions Of Pcbus And Workers*. [online] Available https://www.workcover.nsw.gov.au/law-policy/employer-and-business-obligations/definitions-of-pcbus-and-workers [Accessed 16 May 2016]

Yin, R.K., 2009. *Case Study Research: Design and Methods*. 4th ed. USA: SAGE.

INVOLVEMENT AND INFLUENCE OF CONSTRUCTION PROFESSIONALS FOR ENVIRONMENTALLY SUSTAINABLE DESIGN OUTCOMES

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ABSTRACT

Environmental sustainability is concerned with protecting and conserving both biodiversity and the environment, by reducing waste, preventing pollution and using water and other natural resources as efficiently as possible. Environmental sustainable objectives can be achieved by making appropriate decisions at the design stage with the involvement of different design professionals. Therefore, it is vital to attain the environmentally sustainable design target with the concept of integration. Integration is the combination of involvement and influence for decision making by design professionals. This integration should have to be executed at each stage of the decision-making process to achieve environmentally sustainable design outcomes.

Hence, the aim of this research study is to investigate the level of involvement and influence of construction professionals at the design stage in achieving environmentally sustainable design outcomes. Firstly, a literature synthesis was carried out to study the concept of integrated decision making. Subsequently, the process of decision making is identified from the literature synthesis. Then, a case study strategy was conducted to investigate the general involvement of key professionals for decision making in the design stage and to investigate the level of influence of professionals for decision making in the design stage

The findings revealed that Architect is the key decision maker and the professional who has the highest influence on decision making. Quantity Surveyors and Engineers have the second and third highest levels of influence for decision making at the design stage respectively.

Keywords: *Construction Industry; Design Stage; Environmental Sustainability; Integrated Decision Making.*

1. INTRODUCTION

Sustainable development in construction industry aims to attain the best quality of a construction product by using resources in an efficient way (Office of Government Commerce [OGC], 2007). Currently, "Sustainability" has become a significant issue incorporated with designing (Hill and Bowen, 1997). Hill and Bowen (1997) has further noted that in present community priorities, authorities and developers draw their attention to this issue of "Sustainability", while the public are more keenly aware of the environmental issue. Sustainability comprises three main pillars as environmental sustainability, social sustainability and economic sustainability (Longden *et al*., 2009). Among these three pillars the main focus of this research is on environmental sustainability as it is a universal necessity in the current era (Buhovac and Epistein, 2014).

Environmentally sustainable outputs are not a novel experience to the world as it has been in use for a long time (Chapman, 2015). Dedeurwaerdere (2014) mentioned five notable stages of a sustainable construction project. They are design, construction, operation, facility management/maintenance and facility disposal. As stated by Longden *et al*. (2009), design plays a key role out of all the other phases while facilitating sustainability through reducing cost, improving safety and health as well the image. Further, Hill and Bowen (1997) described that sustainable output at the design stage implies an intention to find the best solution while balancing functional, technical, financial, environmental factors and aesthetic appearance.

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Designing is a team work and joint decisions should have to be taken to achieve the design goals while improving coorporation among individuals (Lahdenpera, 2012). Generally, a professional team in the design stage comprise with Architects, Structural Engineers, Quantity Surveyors, Project Managers, Interior Designers, Landscape Architects, Hydraulic Engineers, Mechanical and Electrical Engineers, etc. (Lahdenpera, 2012). Kibert (2012) noted that as sustainable construction requires joint decisions in the team to achieve common goals effectively. Ratcheva (2009) mentioned that these professionals in the design stage make a 'design team' by combining interpersonal interactions, knowledge diversity and work practices.

A better sustainable design output requires multiple professional skills and judgments, which could be facilitated through integrated decision making (Baiden and Price, 2011). Herein, "integration" can be taken as a combination of 'involvement' and 'influence'. According to the Oxford Dictionary of English (2010), "involvement" is the contribution for a process, whereas, "influence" is the capacity of making an effect on any kind of a process. Integrated decision making provides benefits such as sharing financial and other risks jointly, reducing cost overruns, setting a target cost, reducing time overruns etc. (Lahdenpera, 2012). Integrated decision making should have to be done at each stage of the decision-making process. Karsak and Ozogul (2009) argued the necessity of integration in decision making rose in order to prevent of having unrealistic independent assumptions and to have the most appropriate decision with required cost, quality and the time period. Therefore, as Baiden and Price (2011) mentioned, a better sustainable design output can be attained through integrated decision making on a well-defined decision making process.

Relatively less attention has been given in literature on exploring the decision making process of professionals' to make decisions at the design stage towards sustainability goals. Even the researchers who have addressed this area tend to talk only about the "involvement" aspect instead of "integration" (Polgaspitiya, 2007). Therefore, the need of addressing on integrated decision making concept along with decision making process is identified. Therefore, the aim of this paper is to fill this research gap by exploring the involvement as well as the level of influence for decision making by selected key professionals at the design stage in achieving environmentally sustainable design outcomes. In addressing this aim, the paper first provides a review the concept of "integrated decision making" and its necessity for achieving sustainable design outcomes. It then goes on to discuss the general involvement and the level of influence of key professionals for sustainable decision making in the design stage.

2. DECISION MAKING APPROACHES FOR ENVIRONMENTALLY SUSTAINABLE DESIGNS

As Bader *et al*. (2005) mentioned decision making process starts from formulation. Then sequentially, analysis (making predictions), search (gather potential solutions for requirements), then development of decision making stages (each solution evaluated to find the best alternative), finally specification and modifications should be done. Above facts show that "decision making" become one of those steps in the above-mentioned formulation to specification and modification process. This research is focused on decision making during the design stage by professionals, towards an environmentally sustainable output.

Chen *et al*. (2015) mentioned that there are two approaches of decision making namely, Conventional and Integrated decision making approach. As they identified, in conventional approach, a single entrepreneur is doing all the planning, directing and controlling of activities of subordinates. In the integrated approach, tasks are divided into sub tasks. Sub tasks are managed by individuals with the use of involvement and influence of each other (Akintoye *et al*., 2000). Herein, integration is involves a 'rethinking' of traditional way of doing things in the construction industry. Therefore, decision making through integration will be a new direction to enhance the performance in the construction industry (Malczewski and Rinner, 2015). The American Institute of Architects [AIA] (2007) has highlighted that in integrated decision making, the ability of decision making should not vest in a single team member. All should participate for decision making and only in that occasion the real integration occurs. Further, AIA (2007) described that all decisions should have to be taken in the best interest of the project.

When compared these two approaches integrated approach provides benefits such as saving of time, motivation to attain goals, reduction of conflicts, high commitment, mutual trust and customers' satisfaction than conventional approach (Malczewski and Rinner, 2015).

3. INTEGRATED DECISION MAKING OF PROFESSIONALS IN THE DESIGN STAGE

Decision making power in the design stage is mainly incorporated with the design professionals Davis and Goetsch (2014). Although end user has the chance of expressing their opinions, they do not have the decision-making power (Hansson *et al*., 2010). Hill and Bowen (2007) mentioned that multitude of decision makers are getting together for integrated decision making. The a professional integration phases to achieve a better design outcome can be shown as given in Figure 1.

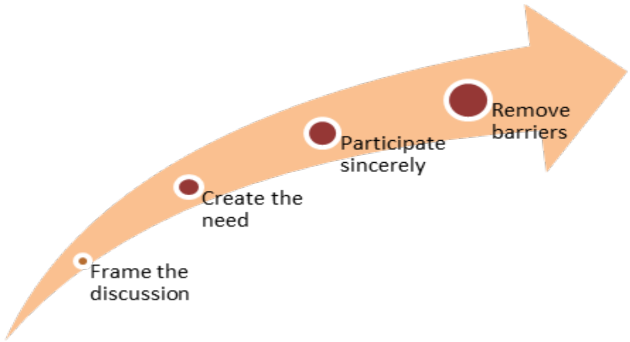

Figure 1: Steps of Better Professional Integration

(Source: Sive, 2009)

Hill and Bowen (1997) discovered that a design professional who wishes to influence a project, should initially involve in discussion as well in decision making. Professionals in the design stage required a better guidance for this complex decision making process (Hill and Bowen, 1997). In that occasion, the requirement of a conceptual decision making process come to the stage. In integrated design decision making whole design professionals has relative responsibility for whole task and they should possess variety of task related skills (Freeman *et al*., 2008).

4. DECISION MAKING PROCESS AT THE DESIGN STAGE FOR ACHIEVING ENVIRONMENTALLY SUSTAINABLE DESIGN OUTCOMES

Decision making process is a listing which supports to define the prevailing functioning background of a specific work load (Boone and Snowden, 2007). Further, a proper decision making process enables professionals to make required decisions in a contextually appropriate manner in separate stages of the process (Boone and Snowden, 2007). As Davis and Goetsch (2014) mentioned when a decision is taken, there should be a structured tool to guide it. Therefore, in an integrated decision making process, requirement of a well-defined decision making process becomes more vital concern. A decision-making process to achieve sustainable outcomes in construction projects incorporates the steps shown in Figure 2 and these key steps are explained below:

Define the problem (Identification of the decision/s to be made) to achieve environmentally sustainable design: Defining the problem is the initial stage of the decision-making process (Refer Figure 2). When it is applied for design decision making, design professionals first get together and define the problem with high design professional agreement. Then solution should have to be proposed to satisfy professionals (Duecker and Khalili, 2013). The availability of information always matter the design decisions as well cost related decisions (Hill and Bowen, 1997). When design affects for a change, cost matter effects on the design change.

Identify design objectives: In order to identify the effective solution, the prior identification of objectives becomes vital (Freeman *et al*., 2008). Environmentally sustainable objectives can be defined according to the client's brief (Refer Figure 2).

Define Criteria for Selection and Prioritize Criteria: Criteria can be set according to the professional judgments (Duecker and Khalili, 2013). Therefore, professionals in the design stage should integrate to set criteria related to the decision to be made (Refer Figure 2). Compare the elements accordingly what gives most benefit, opportunities, most cost and risk (Demirtas and Utsun, 2008).

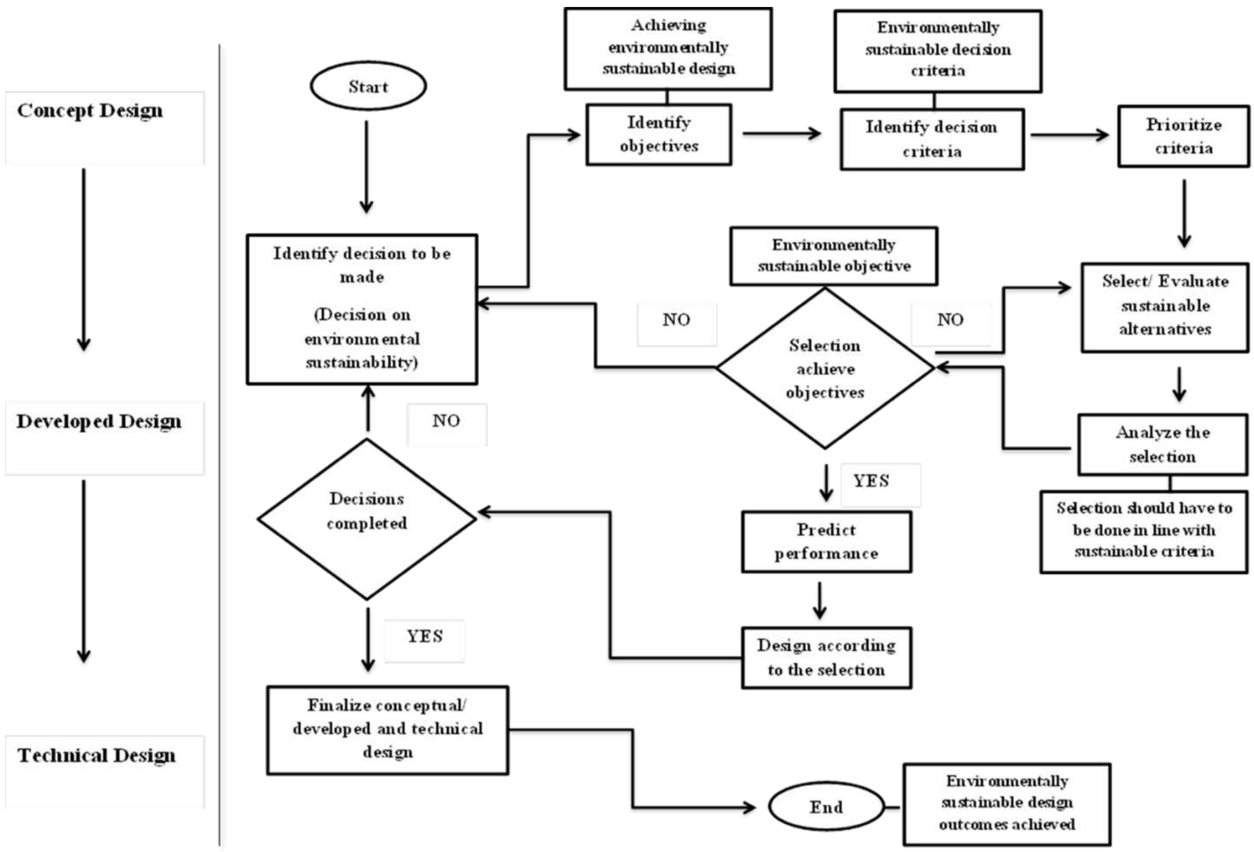

Figure 2: Decision Making Process to Achieve Sustainable Outcomes

Source: Davis and Goetsch (2014)

Examine, evaluate and choose alternatives: As Paveglio and Prato (2014) mentioned examining, evaluation and choosing alternatives can be named as stimulating various objectives taken by various patterns considering different alternatives. This idea can be implemented in this stage while ranking feasible patterns and determine the best. This stage will be an input for the next stage of design decision making process (Refer Figure 1). Alternatives should be generated with the integration of design professionals (Duecker and Khalili, 2013).

Choosing Alternatives:

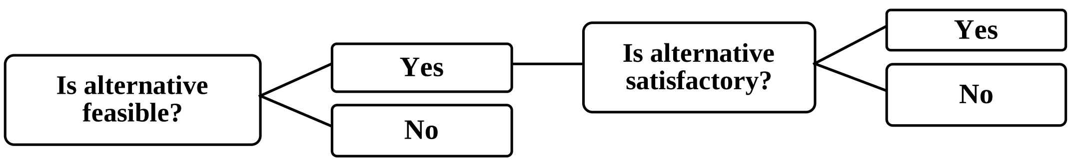

Figure 3: Choosing Most Possible Alternatives
Source: Freeman *et al.* (2008)

As Freeman *et al.* (2008) mentioned this feasibility can be in monetary, legal and ethical forms to achieve environmentally sustainable outcomes (Refer Figure 3). After weighting alternatives, this method can be used to find out most possible design alternatives.

Implement and Monitor Decisions: Freeman *et al*. (2008) further stated that, in order to implement and monitor decisions first there should be the identification of who decides. That can be measured by role of professionals for decision making at all stages. It is better if there is a leading professional for decision making at each stage. Then required resources, budget, schedules for work, detailed plans for uncertain situations and steps to deal with consequences should be made (Freeman *et al*., 2008). This decision-making process should be done continuously until design is completed and environmentally sustainable design outcomes achieved. It is vital to monitor every stage closely by the professionals with client’s requirements to have the best design outcome.

5. RESEARCH METHODOLOGY

This research aims to investigate the level of influence and involvement of construction professionals at the design stage in achieving environmentally sustainable design outcomes. Therefore, a qualitative approach using case studies was adopted for this research. Initially, a comprehensive literature review was carried out to gain the knowledge in integrated decision making concept and to investigate decision making process at the design stage.

Then, preliminary interviews were conducted with expert professionals from two different reputed consultancy firms who have had experience in environmentally sustainable construction projects locally. The data collected through preliminary interviews were used to develop the interview guideline and to identify the professionals to be interviewed at case study stage. According to the professionals' opinions Architects, Engineers and Quantity Surveyors (QS) are the professional categories who majorly involve at the design stage. As Engineer category is comprised with various Engineering disciplines, preliminary interviews guided the researcher to conduct interviews with Engineers in various natures (Structural, Service Engineers etc.).

Then, three case studies were selected in order to investigate the general involvement of key professionals for decision making in the design stage. Environmentally sustainable projects at the design stage are encountered as cases. The selected three cases for this research are given in below Table 1.

The data which was collected through semi structured interviews within case studies were used to analyze by content analysis using QSR NVivo (Version 10).

Table 1: Description of Selected Cases

Case Study No	Project Location	Building Type	Project Cost (Sri Lankan Rupees)	Identified Environmentally Sustainable Features	Interviewee Details
1	Galle (Kosgoda)	Hotel Building	125millions	**Indoor Environment Quality** – Indoor Air Quality and Lighting Environment	Project QS (Q1) Chartered Architect (A1) Chartered Engineer (E1)
				Material Usage -Eco friendly materials usage (Re usable/ Natural/ Used materials)	
				Building Amenities – Visual Quality and Comfort (Proper day light quality and comfort)	
				Water Management – Water Conservation	
2	Colombo (Homagama)	University Building	8.6 Billions	**Indoor Environment Quality** - Health and Hygiene, Indoor Air Quality, Lighting Environment	Chartered QS (Q2) Chartered Architect (A2) Chartered Engineer (E2)
				Building Amenities –Adaptability	
				Resource Use - Energy Efficiency	
				Water Management - Water Conservation	
				Material Usage - Eco Friendly material Usage	
				Solid Waste Management - Waste sorting and storage	
3	Colombo 6	Office Building	150 millions	**Water Management** - Water Conservation	Chartered QS (Q3) Chartered Architect (A3) Chartered Engineer (E3)
				Solid Waste Management - Waste sorting and storage	
				Material Usage -Eco friendly materials usage	

6. ANALYSIS AND RESEARCH FINDINGS

6.1. *INVOLVEMENT OF PROFESSIONALS IN DECISION MAKING DURING DIFFERENT STAGES OF THE RIBA PLAN OF WORK: CASE STUDY FINDINGS*

RIBA plan of work is the most common plan of work used in the construction industry due to its benefits such as RIBA provides clear boundaries, details of tasks and required outputs at each stage. Therefore, it is better and advisable to follow RIBA plan of work at the design stage to have the best outcome while taking design stage decisions. Practically in industry RIBA plan of work is practiced within limits but not restricted to it. According to the interviews the role of each professional in relation to decision making in design stages can be divided into several sections such as;

a. Key decision maker – Professional who act as the key personnel in decision making
b. Responsible for overseeing activities – Professional who responsible to take decisions considering future risk involvement as well future activities
c. Responsible for documentation
d. Advising – Professional who advice other professionals regarding the decisions to be taken or already taken
e. Responsible for assessments – Professional who responsible on evaluating the decisions already taken

Figure 4 shows the involvement of Architects, Quantity Surveyors and Engineers in terms of the aforementioned roles in design stage decision making.

Professional	**Concept Design**	**Developed Design**	**Technical Design**
Architects	**(a) (b) (c) (e)**	**(a) (c) (d) (e)**	**(a) (c) (d) (e)**
Quantity Surveyors	**(b) (d) (c)**	**(b) (c) (d)**	**(b) (c) (d)**
Engineers	**(d) (b) (e)**	**(b) (e) (d)**	**(a) (b) (d) (e)**

Figure 4: Industry Practice of RIBA Plan of Work at Design Stage

The findings of above Figure 4 can be summarised follows:

- All the professionals in every case are involving in each stage in the RIBA plan of work.
- In each case, Architects are the professionals who make key decisions at every design stage.
- Irrespectively, every professional should be responsible for overseeing activities before taking decisions.
- Although, Architects are the key decision makers, Quantity Surveyors and Engineers are the key advisers at each design stage.

6.2. *DECISION MAKING FOR SUSTAINABLE PROJECTS AT THE DESIGN STAGE: CASE STUDY FINDINGS*

Environmentally sustainable project characteristics required better level of decision making to resolve design stage obstructions. Therefore, design stage problems required lot of structuring and rational problem solving. Normally in the construction industry decisions are taken in the design stage within several phases as shown in below Figure 5.

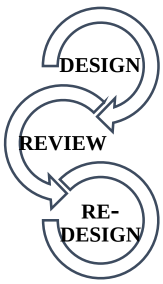

Figure 5: Project Development Stages

According to Figure 5, at the end of each design stage in the RIBA plan of work, the design team should ensure that all the design issues are addressed through the completed design at the reviewing stage.

Interviewee Q1, Q3 and A3 described below as factors affecting for the involvement of decision making process;

- Knowledge access and the management
- Thinking skills and communication skills (Meetings, informal gatherings etc. assists to enhance the involvement for decision making)
- Use of strategy to solve problems and the way of giving solutions

According to the above bullet points, the professionals who are with better knowledge and management skills, communication and thinking skills, problem solving skills and solution providing skills are able to involve for decision making than others.

6.3. Professional Involvement for Decision Making at the Design Stage: Case Study Findings

Each interviewee in each case study defined themselves and their role for decision making in terms of a) a leading role, b) a combination of leader and supportive roles, c) a role with supportive characteristics and d) a combination of supportive and follower roles (refer Table 2).

Table 2: Professional Opinion for Decision Making (Cross case analysis)

Professional Opinion	Architect Category			QS Category			Engineers Category		
Interviewee	A1	A2	A3	Q1	Q2	Q3	E1	E2	E3
• Leader	Y	Y	Y						
• Leader/ Supportive						Y	Y		Y
• Supportive				Y	Y			Y	
• Supportive/ Follower				Y					

*Y- Yes

As per Table 2 above, it was identified that among all the professionals, Architects play a dominant role in decision making. Respondents also noted that Architects, sometimes have over involvement in decision making particularly in relation to drawing development and documentation. This over involvement directly affects the Quantity Surveyors' involvement. Therefore, Architect's involvement for decision making can be defined as a "Leading Role" in most of the design decision making stages.

Generally, Quantity Surveyor's involvement can be defined as "Supportive Role". However, at times Quantity Surveyors become "Leader plus a Supportive Role" particularly in relation to cost related decisions. The Quantity Surveyor basically supports the decisions of commercial aspects, which influence the Architect and the Engineer in the design stage. The respondents also noted that the practicability and the sustainability of the construction project mainly depend on the Quantity Surveyor's involvement, as other professionals' typically are not much concerned with meeting required regulations and achieving budget limits.

Engineer is a professional who is mainly involved in decision making regarding structural matters, services, mechanical and Electrical works. In other stages, the Engineer has a supportive role and is an identical active member in the design team. Engineers generally involve for design review decisions, design coordination, structural integrity related decisions while understanding budget constraints. Further, he is a flexible character in decision making with respect to the Architects' and Quantity Surveyor's ideas. Therefore, in general, Engineer's involvement for decision making can be defined as "Leader plus a Supportive Role".

7. Conclusions

The aim of having Environmentally Sustainable outcomes has been vastly increased in current years due to the knowledge and understanding of local as well international issues related to environmental sustainability.

Obtaining environmentally sustainable outcome is a group task which require lots of professional skills and experiences required. Therefore, this research introduces the term “integration” which makes the combination of professional involvement and influence. Best skills and experiences make professionals to have best decisions towards the productive project outcome. Therefore, integrated decision making is, the involvement and influence of professionals for decision making towards a specific goal. The design stage can be defined as an utmost important stage in RIBA plan of work. Therefore, a decision-making process for the design stage is a guidance for environmentally sustainable design outcomes. As identified in Figure 2, decision making process comprises with seven notable stages for the design stage, such as identifying decisions to be made, identify client’s objectives, identifying and prioritizing decision criteria, selecting and proposing alternatives analyzing the selection made, predicting performance and finalizing the design. According to the analysis, all three professional categories (Architects, Engineers and Quantity Surveyors) are involving for each stage of the decision-making process. But the highest involvement can be identified from the Architect, compared to other two professional categories. Architect is the key decision maker and other two professionals are acting as supporters in the decision-making process toward environmentally sustainable outcomes. In some cases, Engineer and Quantity Surveyor too act as leaders in decision making. But as an overall picture, the highest involvement for decision making is from the Architect. Involvement for decision making by Quantity Surveyors and Engineers can be seen in an average equal state towards environmentally sustainable outcomes.

8. REFERENCES

Akintoye, A., Black, C. and Fitzgerald, E., 2000. An analysis of success factors and benefits of partnering in construction. *International journal of project management,* 18(6), 423-434.

Bader, H.A., Kartam, M., Reshaid, K. A. and Tewart, N., 2005. A project control process in pre-construction phases: focus on effective methodology. *Engineering construction and architectural management*, 2(4), 351-372. doi: 10.1108/09699980510608811 [Accessed 20 June 2015].

Baiden, B. K. and Price, A. D. F., 2011. The effect of integration on project delivery team effectiveness. *International Journal of Project Management*, 29, 129-136.

Batuwangala, I. D., 1996. *The Involvement of Professionals in the Construction Contractor Organizations of Sri Lanka*. (Unpublished dissertation B.Sc.). University of Moratuwa, Moratuwa, Sri Lanka.

Boone, M. E. and Snowden, D. J., 2007. A leader’s decision making process for decision making. *Harvard Business Review,* 85(11), 68-76.

Buhovac, A. R. and Epstein, M. J., 2014. *Making sustainability work: Best practices in managing and measuring corporate social, environmental, and economic impacts*. Berrett: Koehler Publishers.

Chapman, J., 2015. *Emotionally durable design: objects, experiences and empathy*. 2nd ed. London: Taylor and Francis Group.

Chen, X., Liang, D., Xu, X. and Zhou, Y., 2015. A risk elimination coordination method for large group decision-making in natural disaster emergencies. *Human and Ecological Risk Assessment: An International Journal*, 21(5), 1314-1325.doi: 10.1080/10807039.2014.955394 [Accessed 13 May 2015].

Chuang, M. E. N. G., 2014. The Sustainable Design Strategy in Product Conceptual Design. *Packaging Engineering*, 2, 021.

Davis, S. and Goetsch, D. L., 2014. *Quality management for organizational excellence*. [DX Reader Version]. Retrieved from http://abufara.com/abufara.net/images/abook_file/back/Ch1.pdf [Accessed 9 July 2015].

Dedeurwaerdere, T., 2014. *Sustainability science for strong sustainability*. Cheltenham, UK: Edward Elgar Publishing Limited.

Demirtas, E.A. and Ustun, O., 2008. An integrated multi objective decision making process for supplier selection and order allocation. *The International journal of management science,* 36(1), 76-90.

Deng, Y. M. and Edwards, K. L., 2007. The role of materials identification and selection in engineering design. *Materials and design,* 28(1), 131-139. doi: 10.1016/j.matdes.2005.05.003 [Accessed 4 April 2015].

Duecker, S. and Khalili, N.R., 2013. Application of multi criteria decision analysis in design of sustainable environmental management system decision making process. *Journal of clearer production,* 47, 188-198.

Eppinger, S.D., Rowles, C.M. and Sosa, M. E., 2003. Identifying modular and integrative systems and their impact on design team interactions. *Journal of Mechanical Design,* 125(2), 240-252. doi: 10.1115/1.1564074 [Accessed 5 June 2015].

Freeman, R.E., Gilbert, D.R. and Stoner, J.A.F., 2008. *Management*. New Delhi, India: PHI Learning Private Limited.

George, W.N.B., Sacher, H.P., Willis, A.J. and Willis, C.J., 1981. *The Architect in practice*. 6th ed. London: Granda publishing

Hansson, B., Pamsel, S. and Widen, K., 2010. Managing the need of end users in the design and delivery of construction projects. *Facilities,* 28(1/2), 17-30.

Hill, R.C. and Bowen, P.A., 1997. Sustainable Construction: principles and a framework for attainment. *Construction Management and Economics*, 15(3), 223-239.

Karsak, E.E. and Ozogul, C.O., 2009. An integrated decision making approach for ERP system selection. *Expert systems with applications*, 36(1), 660-667. doi: 10.1016/j.eswa.2007.09.016 [Accessed 25 April 2015].

Kibert, C. J., 2012. *Sustainable Construction: Green building design and delivery*. 4th ed. Canada: John Wiley and Sons.

Lahdenpera, P., 2012. Making sense of the multi-party contractual arrangements of project partnering, project alliancing and integrated project delivery. *Construction Management and Economics*, 30(1), 57-79.

Longden, J., Pitt, M., Riley, M. and Tucker, M., 2009. Towards sustainable construction: promotion and best practices. *Construction Innovation*, 9, 201-224.

Malczewski, J. and Rinner, C., 2015. GIS-MCDA for Group Decision Making. *In Multicriteria Decision Analysis in Geographic Information Science*. 223-247. doi: 10.1007/978-3-540-74757-4_8 [Accessed 3 May 2015].

Office of Government Commerce., 2007. *Achieving excellence in construction procurement guide*. Sustainability. London: Office of Government Commerce.

Paveglio, T.B. and Prato, T., 2014. An integrated conceptual decision making process for adapting forest management practices to alternative futures. *International journal of forestry research*, 2014(2014), 1-13.

Polgaspitiya, P. W. D. N. B., 2007. *Effective involvement of Quantity Surveyors in Managing the Critical Risk factors in Road Construction Project in Sri Lanka* (Unpublished dissertation B.Sc.). University of Moratuwa, Moratuwa, Sri Lanka.

Ratcheva, V., 2009. Integrating diverse knowledge through boundary spanning processes – The case of multi-disciplinary project teams. *International Journal of Project Management*, 27, 206-215

Sive, T., 2009, July. Integrated project delivery: reality and promise- a strategic guide to understanding and marketing IPD. Retrieved from http://www.tedsive.com/docs/Sive_White_Paper_IPD.pdf [Accessed 29 March 2015].

Stevenson, A., 2010. *Oxford dictionary of English*. 3rd ed. Oxford: Oxford University.

The American Institute of Architect. 2007. *Integrated project delivery: A guide.* Washington: The American Institute of Architect.

IPD AND BIM: MAKING SENSE OF CHAOS?

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ABSTRACT

Why is BIM not working? Where in the world do we really have IPD (integrated project delivery)? The U.K. has failed to achieve its Level 2 BIM goals. Hong Kong is striving to implement true collaborative contracting with pain share/gain share. Where really do the problems lie?

In a recent online article Boutle (2017) stated "Not all of the UK government central departments are BIM Level 2 ready despite being almost a year into the mandate." and followed up with "Supply chain drivers for adopting BIM are mainly to satisfy the end client, not to look at internal benefits of improved information management, smarter working and gaining efficiencies." So, one of the BIM-leading nations that was heading the drive to implement BIM on all government projects by 2016 has missed its target by some considerable distance. It is obvious from the evidence and rhetoric that BIM is not well understood, well accepted nor of value to many in the supply chain. Therefore, it is not the panacea for increased industry efficiency and effectiveness that it was held up to be. Why not?

What is really happening? We present a case study that explores current BIM implementation for MEP (mechanical, electrical, plumbing and fire safety systems) coordination in Hong Kong. Data were collected by ethnographic participant observation over 4 months and one-on-one interviews from a social network perspective. We found that BIM implementation in Hong Kong is currently at a low "maturity" level with little transformation of existing procurement routines and with professionals still following their traditional roles within project teams. Collaborative contracting and IPD exist on very few projects. Plans to add high-value professional expertise into project delivery through BIM-enabled IPD adoption are not working in Hong Kong's construction industry. This is partly due to team members' reluctance to change and the power conflicts (bolstered by arcane contract terms) between organisations in the teams thwarting collaboration. Professionals' perceptions and attitudes towards BIM are embedded in the view they have of their social context. Power conflicts generated from hierarchical organizational structures and silo mentalities are a major challenge in implementing BIM-enabled IPD.

Keywords: *BIM; Integrated Project Delivery (IPD); Process Innovation; Professional Silos; Socio-technical Systems; Social Network Analysis (SNA).*

1. INTRODUCTION

The construction industry has been widely criticized for its fragmentation (Shirazi *et al.,* 1996; Baiden *et al.,* 2006; Howard *et al.,* 1989; Ahmad *et al.,* 1995). This is due to the rational human reflections embedded in the traditional culture of the construction industry over decades (Xue *et al.*, 2010), where the participants focus more on self-protection and economic benefits rather than excellent performance in project delivery (Latham, 2004; Egan, 1998). Increased complexity of construction projects (Gidado, 1996), lack of accurate building information and ineffective communication within project teams (Higgin *et al.*, 1965) are all reasons for this poor collaborative working environment, which leads to unsatisfactory project performance on all dimensions: time, cost, safety and health and quality.

In the last millennium (the 1960s), the Tavistock Institute (Higgin *et al.*, 1965) pilot study of communication in the building industry provided a full picture of communication issues on construction projects. Two major problems emerged: lack of accurate information on buildings to be constructed and poor communication among stakeholders, which led to inefficient building operations. They also indicated that these primary

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communication difficulties stemmed from problems in clearly defining the roles of resource controllers and the complex interaction of technical, economic and social forces (Crichton, 1966). In the follow-up research in 1966, the concepts of interdependence and uncertainty were identified as important characteristics of construction (Crichton, 1966), and were later recognized as the sources of complexity in the construction process (Gidado, 1996). Numerous attempts have been made to construct effective solutions to facilitate communication and collaboration within project teams (e.g. NEC and lean construction).

The integration process of IPD did not start with BIM but was driven by a desire to make project teams more cohesive, collaborative and competent (see, for example, Rowlinson and Matthews (1999) and Cheung et al (2005). However, researchers have suggested that BIM's positive impact as a driving-force on the integration of the construction project team should be emphasized (Taylor and Bernstein, 2009). In their research, they developed four paradigms for BIM implementation, which in terms of evolving order are visualization paradigm, coordination paradigm, analysis paradigm and supply chain integration paradigm. According to their findings, BIM's role in construction team integration evolves from the preliminary paradigm of visualization to advanced level of supply chain integration with increasing project experience at a firm-level. They also assert that each paradigm has a different impact on final project performance: if the paradigm adopted by the stakeholders at firm-level in the AEC industry does not evolve to a higher paradigm, it would be unrealistic to expect to fully realise the advantages that BIM brings (Taylor and Bernstein, 2009). Underpinning this argument, but rarely articulated, is the need for information and information flows that enable collaboration. Thus, currently, we find ourselves in a partial BIM world with imperfectly integrated project delivery.

Though BIM was proposed as an innovative solution to the fragmentation of the construction industry, the nature of fragmentation itself turns out to be one of the factors inhibiting further successful implementation of BIM (Gu and London, 2010). Observation of current BIM practice indicates that a collaborative atmosphere with collective participation and contributions from all the stakeholders in a building project is highly effective (Gu *et al.*, 2008), rather than the innovation of BIM itself. In fact, Tavistock Institute's study (1965) asserted that improved communication techniques themselves in the construction process will add little value to the improvement of co-ordination and cohesion in the building team. However, the pattern of relationships and responsibilities within project teams have much greater influence on the way communication functions (Higgin *et al.*, 1965). The study conducted by Dossick and Neff (2010) showed that BIM's positive influence on project integration is limited to the technological level; the key to team cohesion is still based on human factors. Our case study in this paper also reveals that BIM's advantages as an efficient and effective collaboration platform are overestimated. Implementation of BIM without moving to IPD and, at the same time, ignoring social and behavioural perspectives that come with process and technological change is the source of many of the problems in leading BIM adopters around the world (Ashcraft, 2008).

Gledson (2017) found that "During implementation stages of BIM innovation adoption, organisations may have to make use of hybrid project delivery methods on initial adopter projects while also working concomitantly with existing systems, processes and personnel not yet ready to adapt to BIM methodology." The key issue he raises is the need for organisational change and development of "hybrid" project delivery processes to enable information flows, information sharing, and information use. Over 50 years after Higgin and Jessop and Crichton the same issues emerge in a more sophisticated socio-technical system. We are still in chaos.

2. SOCIAL NETWORK ANALYSIS

By adopting social network analysis (SNA) to identify and quantify changes in actors' roles and relationships (Pryke, 2004), this case study explored the driving-forces for effective integration of the project team.

An accepted definition of SNA is given by Mitchell (as cited in Loosemore, 1998), which is "a specific set of linkages among a defined set of persons, with the additional property that the characteristics of these linkages as a whole may be used to interpret the social behaviour of the persons involved." Podolny and Page (1998) provided a definition of an inter-organizational level network as various patterns of collaboration, including joint venture, strategic alliances, business groups, franchises, research consortia, relational contracts, and outsourcing agreements. In fact, the concept of social network is widely used from the interpersonal level to the international level (Bazzoli *et al.*, 1998; Park *et al.*, 2009; Schilling and Phelps, 2007; Van Raak and Paulus, 2001). SNA is useful in providing a stage for a fresh perspective on socio-technical studies.

In construction projects, formal and informal relationships of stakeholders can be depicted as social networks, the points or nodes represent the stakeholders and the lines indicate the relationships. By analysing characteristics of social networks, important information can be explored, such as “who is the key stakeholder to the project’s success”, “How do themain contractor and sub-contractors cooperate with each other”, “How effective is cooperation” and “How has each stakeholder performed?”

3. SNA CASE STUDY FINDINGS AND DISCUSSION

3.1. EMBEDDED NORMS AND PROFESSIONALISM

Embedded norms (the customary rules that govern behaviour) `appeared as a great hindrance to successful BIM implementation. Any innovation’s implementation will inevitably go through a process from original tentative or compulsory adoption to norm change and then on to culture formation. Before the innovation is completely accepted by a given group, the old working paradigm plays the role of inhibitor. An interesting phenomenon in our third site visit occurred; we witnessed a direct 2D drawing exchange and submission rather than formal submission to the integrated database of BIM. A designer from sub-contractor A delivered a copy of an updated drawing directly to one of the BIM coordinators. This may save time and effort to submit and download from the database for one team; however, this behaviour led to disputes later because no formal records appeared in the BIM system. Another interviewee flagged this as normative behaviour that happened frequently during team members’ daily information exchanges. This confirmed that BIM is not actually accepted by the construction team as a powerful information storage and exchange system and, more importantly, IPD is thwarted by such actions.

Interviewees indicated that there is indeed a misconception that BIM is a 3D model not an information repository. Thus, it is essential to create a new professionalism within project teams to improve collaboration enabled by BIM systems. Professionals’ motivation to voluntarily collaborate, to share knowledge and sharpen their skills are all based on their value judgments and the formulation of moral and ethical codes, internal power structures and professional silos. SNA enabled the exploration of formal and informal relationships among project teams and the impact on IPD implementation.

The formal relationships embedded in the contract and the organization chart stimulate power conflict and hierarchy among team members. This works against developing an effective mechanism to facilitate better collaboration. In the Hong Kong context team members’ decisions depended on their superiors’ instruction, reducing project team efficiency. However, by appropriately utilizing the formal system, the effectiveness of team collaboration can be improved. In our cases, for example, if an individual started to exert a negative influence on team collaboration, complaints were made to senior managers; by rearranging members in intra- and inter-team groups collaboration effectiveness was enhanced although the decision-making process was less efficient.

Compared with formal structure, informal networks of relationships are less powerful in decision making but engender mutual trust and social capital enabling smoother information exchange and knowledge sharing (see, for example, Koh *et al.,* 2015). In the context of IPD, responsibilities are more explicit but professionals are driven to learn across disciplines. Knowledge sharing is a characteristic of successful IPD implementation.

3.2. ROLE CHANGE AND PROFESSIONAL SILOS

Nominal role change was observed during the IPD implementation process. With BIM, new positions such as “BIM coordinator, model coordinator and BIM manager” emerge. These coordinators were promoted from positions of draftsman, modellers, CAD supervisors or MEP engineers. They do the same coordination work in an IPD project as they did in the previous traditional projects, in other words, the role changes are nominal with similar work content and procedures. BIM merely provided advanced visualization techniques for clear coordination rather than a new pattern of collaborative relationships under the role changes. Information was oftentimes not included (physical model LOD1) or not used if it was included. Thus, we have the newly crowned BIM king without his clothes.

On the other hand, the introduction of IPD and BIM brought about role changes. For instance, engineers are skilled at checking section views of drawings and updating all revised 2D drawings in their head. However, it is more convenient and precise to check all the information in the BIM model and so the role of these engineers changed. In our case, the need for engineers reduced as the project proceeded. This change is unnerving for professionals if not managed by training, redeployment and providing employee satisfaction with a more rewarding and less stressful role (see, for example, Yip et al, 2008 and Lingard *et al*, 2007)

3.3. ORGANIZATIONAL BIM CAPACITY AND PROFESSIONAL SILOS

An organization's BIM capacity is based on its professional competences. If organisations can discard the criteria of profit growth and cost reduction first and combine social and environmental considerations during their business operations, they will appreciate BIM's core value for facilitating the removal of fragmentation in the construction industry through providing an information processor for IPD. The goals and ideals of IPD can be achieved through this facilitation only if the change is managed. This change is causing organisations to rethink and redefine "the nature and scope of their service, as well as the concept and understanding of project value". The focus is moving toward improving IPD capacity in order to meet or to drive the market trend in Hong Kong towards collaborative contracting underpinned by the NEC contract with pain share, gain share.

3.4. LOCATION-DEPENDENT CHANGE AGENT AND PROFESSIONALISM

The nature of the change agent is of great importance to an innovation's adoption. The agent often needs to come from a different location and cultural background because the vast majority think in traditional system paradigms that are closed and ingrained. For instance, institutions such as the American Institute of Architects, University Offices of Physical Plant and several major engineering companies have driven IPD implementation in the USA. In Australia, several major contractors are enthusiastic proponents whereas MEP companies are driving BIM adoption in a non-IPD environment. In mainland China, due to institutional stasis and rigid governance structures, further BIM implementation for integrated project delivery is facing tremendous challenges.

3.5. MATURITY OF IPD, BIM AND PROFESSIONALISM

Based on his Capability Maturity Model, Succar (2009) assesses BIM (and IPD) maturity within industry, organizations, and individuals. The term maturity defines the quality, repeatability, and degree of excellence within a specific field, be it BIM or IPD. In his studies, Succar defined each stage as having specific attributes (Succar, 2010):

- Initial / Ad-hoc stage
- Defined stage
- Managed stage
- Integrated stage
- Optimized stage

Recognizing where an organization sits and moving it through planned change is essential for IPD implementation. This socio-technical system is reliant on people with talent and training, organization structures that are flexible, responsive and supportive and technology that is readily accessible and facilitates information sharing. Companies need to make use of maturity models to facilitate and monitor improvement of their capabilities and achieve the benefits that come from process improvement (Dossick and Neff, 2010).

The professional silos need to be broken and a climate of trust and collaboration engendered, with best for project philosophy underpinning the project teams' actions. The technological change agent has been BIM. To continue this process, the social change agent must be institutional and team leadership. IPD is a process that is facilitated by information sharing (BIM) and is founded on trust and collaboration (people).

4. REFERENCES

Ahmad, I. U., Russell, J. S. and Abou-Zeid, A., 1995. Information technology and integration in the construction industry. *Construction management and economics*, 13(2), 163-171.

Ashcraft, H. W., 2008.Building information modelling: A framework for collaboration. *The construction lawyer*, 28(3), 1-14.

Baiden, B., Price, A. and Dainty, A., 2006.The extent of team integration within construction projects. *International journal of project management*, 24(1), 13-23.

Bazzoli, G. J., Harmata, R. and Chan, C., 1998. Community-based trauma systems in the United States: An examination of structural development. *Social science and medicine*, 46(9), 1137-1149.

Boutle, A.2017.*UK BIM adoption: reality is difficult to fathom*. [Online]. Available from:http://www.bimplus.co.uk/people/uk-bim-adopt7ion-rea6lity-diffic8ult-fathom/ [Accessed April 19, 2017]

Cheung, F.Y.K., Rowlinson, S., Jefferies, M. and Lau, E., 2005. Relationship contracting in Australia. *Journal of construction procurement: special issue on 'trust in construction'*, 11(2), 123-135

Crichton, C., 1966. *Interdependence and uncertainty*: *A study of the building industry*. London: Tavistock Publications.

Dossick, C.S. and Neff, G., 2010. Organizational divisions in BIM-enabled commercial construction. *Journal of construction engineering and management*.136 (4), 459-467

Egan, J.,1998. *Rethinking Construction: Report of the Construction Task Force*. London: HMSO

Gidado, K., 1996. Project complexity: The focal point of construction production planning. *Construction management and economics*, 14(3), 213-225.

Gledson, B.J., 2016. Hybrid project delivery processes observed in constructor BIMinnovation adoption. *Construction innovation*, 16(2), 229-246

Gu, N. and London, K., 2010.Understanding and facilitating BIMadoption in the AECindustry. *Automation in construction*, 19(8), 988-999.

Gu, N., Singh, V., London, K., Brankovic, L. and Taylor, C., 2008. Adopting building information modelling (BIM) as collaboration platform in the design industry. *In*: Nakapan, W., Mahaek, E., Teeraparbwong, K. and Nilkaew, P., eds. *13th conference on computer aided architectural design research in Asia*, 9-12 April 2008 Chiang Mai, Thailand. Chiang Mai:Pimniyom Press/Faculty of Architecture, Chiang Mai University, 1-8

Higgin, G., Jessop, W. N. and Relations, T. I. O. H., 1965. *Communications in the building industry: The report of a pilot study*. London: Tavistock Publications

Howard, H.C., Levitt, R., Paulson, B.C., Pohl, J.G. and Tatum, C.B., 1989. Computer integration: reducing fragmentation in AEC industry. *Journal of computing in civil engineering*, 3(1), 18-32

Koh, T.Y., Rowlinson, S., and Tuuli, M.M.2015.Social capital in construction projects: An exploration. *In*: Froese, T. M., Newton, L., Sadeghpour, F. and Vanier, D. J., eds. *5th International/11th Construction Specialty Conference*, 8-10 June 2015Vancouver. Vancouver: Canadian Society for Civil Engineering,1601-10

Latham, M., 1994. *Constructing the team*. London: HMSO.

Lingard H., Yip B., Rowlinson, S. and Kvan T., 2007. The experience of burnout among future construction professionals: A cross-national study. *Construction management and economics*, 25(4), 345-357.

Loosemore, M., 1998. Social network analysis: Using a quantitative tool within an interpretative context to explore the management of construction crises. *Engineering, construction and architectural management*, 5(4), 315-326.

Park, H., Jeong, W. Y. and Han, S. H., 2009. Social network analysis of collaborative entries for construction firms in international construction projects. In: *26th International Symposium on Automation and Robotics in Construction (ISARC)*, 24-27June Austin Texas. IAARC, 169-175

Podolny, J. M. and Page, K. L., 1998. Network forms of organization. *Annual review of sociology*, 24(1), 57-76.

Pryke, S. D., 2004.Analyzingconstruction project coalitions: Exploring the application of social network analysis. *Construction management and economics*, 22(8), 787-797.

Rowlinson S. and Matthews, J., 1999. Partnering: Incorporating safety management. *Engineering, construction and architectural management*, 6(4), 347-357.

Schilling, M. A. and Phelps, C., 2007.Interfirm collaboration networks: The impact of large-scale network structure on firm innovation. *Management science*, 53(7), 1113-1126.

Shirazi, B., Langford, D. and Rowlinson, S., 1996.Organizational structures in the construction industry. *Construction management and economics*, 14(3), 199-212.

Succar, B., 2009.Building information modelling framework: A research and delivery foundation for industry stakeholders. *Automation in construction*, 18(3), 357-375.

Succar, B., 2010.The five components of BIM performance measurement. *In*: Barrett, P., Amaratunga, D., Haigh, R., Keraminiyage, K. and Pathirage, C., eds. *CIB WorldCongress*, 10-13 May 2010, Salford.Salford Quays: The University of Salford

Taylor, J. E. and Bernstein, P. G., 2009.Paradigm trajectories of building information modelling practice in project networks. *Journal of management in engineering*, 25(2), 69-76.

Van Raak, A. and Paulus, A., 2001. A sociological systems theory of inter-organizational network development in health and social care. *Systems research and behavioural science*, 18(3), 207-224.

Xue, X., Shen, Q.and Ren, Z., 2010.Criticalreview of collaborative working in construction projects: business environment and human behaviours. *Journal of management in engineering*, 26(4), 196-208.

Yip, B., Rowlinson, S. and Siu, O.L., 2008. Coping strategies as moderators in the relationship between role overload and burnout. *Construction management and economics*, 26(8), 871-882.

KEY REENGINEERING ROLES FOR THE SUCCESSFUL IMPLEMENTATION OF BUSINESS PROCESS REENGINEERING PROJECTS IN SRI LANKA

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ABSTRACT

To be highly competitive in present globalised economy, there is a decisive need for organisations to rethink and transform the prevailing business processes for improved quality and efficiency, reduced costs, and increased profitability. This leads to the introduction and evolvement of Business Process Reengineering (BPR) projects in various organisations over the past decades. Since BPR facilitates the organisations to enhance the performance of their business processes, despite the complexity and riskiness of BPR projects, it has spanned numerous industries. Regardless of the extensive adoption, in many instances efforts of BPR implementation has proved unsuccessful. BPR projects often tend to be large with long durations and tend to involve numerous stakeholders. It has been asserted that the selection and organisation of the people, who really do the reengineering, is key to the success of the endeavour. Accordingly, there is a necessity to identify the key stakeholders who should get involved in BPR projects to assure their success. Since the key stakeholders involved in each reengineering project may differ based upon the process being selected for reengineering, this study is aimed investigating the key reengineering roles for the successful implementation of BPR projects.

Altogether, four (4) BPR projects implemented within the last two years in four different organisations in the Western Province of Sri Lanka were selected as case studies to investigate the BPR roles. Findings revealed eight (8) reengineering roles that is needed to facilitate successful implementation of BPR projects in the Sri Lankan context. The functions to be performed by each role during the pre-implementation, implementation and post-implementation phases of BPR projects were also identified. The study revealed two reengineering roles: i.e. 'initiator' and 'reengineering facilitators'; not identified in literature, but were recognised as important in BPR implementation in the Sri Lankan context. In doing so, the paper brings forwards the findings with respect to the key reengineering roles to be involved throughout the BPR projects in the Sri Lankan context.

Keywords: *Business Process Reengineering (BPR); Key Reengineering Roles; Key Stakeholders; Sri Lanka.*

1. INTRODUCTION

Regardless of the industry that they belong to, modern organisations must change themselves to close competitive gaps, achieve high performance standards and survive in a dynamic world (Atkin and Bjork, 2007; Redlein, 2005). In most instances, Business Process Reengineering (BPR) is used to achieve such alterations and optimisations within the processes (Redlein, 2005). Organisations that have enforced reengineering successfully have disclosed that the benefits obtained included quality and productivity enhancement, production cycle time reduction, higher profits, improved customer satisfaction, sales and marketing improvements, machine resources (Tennant and Wu, 2005). Conversely, for many organisations, the consequences of BPR has created a plethora of problems: i.e. low morale, declining unit performance, inconsistency in performance, and threats to main competences and competitiveness (Drago and Geisler, 1997). Since the outcomes of BPR may result in causing either positive or adverse impacts to the organisations (Tennant and Wu, 2005), organisations should attempt to implement the BPR projects meticulously (Schniederjans and Kim, 2003).

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As there are certain key roles that emerge during the implementation of BPR (Bradley, 1994; Hammer and Champy, 1993), selection and organisation of the people who really do the reengineering is vital to assure the project success (Hammer and Champy, 1993). Supporting this view, Khodambashi (2013) stated that since BPR is a top down approach, involvement of the right people in the redesign process is vital and considered to be one of the best practices. Review of literature further revealed that to ensure success, BPR projects must be executed by people within the organisation (Campbell and Kleiner, 2001), they must be involved openly and actively (Jackson, 1997) and should be consulted at all steps on the process. This implies that the reengineering roles can significantly impact the BPR project success. Involvement of several precise players who have vital roles to play throughout the project is essential to avoid issues in BPR implementation and thereby to assure the success. The aim of this paper is to investigate the key reengineering roles, which are essential to ensure the success of BPR projects and the functions to be performed by each reengineering role at different phases of the project.

2. BPR AND ITS APPLICATION

BPR is a management technique which has emerged from the quality movement (Ryan and Hurley, 2004) in the latter part of the 20th century (Alas *et al*., 2012). Review of literature made evident that the concept of BPR as it is known today was first introduced by Hammer in 1990 as a concept of obtaining radical improvements and enhanced business results.

Like other matured disciplines, the definitions of BPR domain also tend to vary, and substantial differences of views exist in relation to what precisely constitutes BPR (Ahmed and Simintiras, 1996). Among the numerous definitions of BPR, the definition provided by Hammer and Champy (1993) is found to be promising since it best encompasses the ideas of key constructs of BPR i.e. process, business process and reengineering. Hammer and Champy (1993, p32) defines BPR as *"fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance, such as cost, quality, service, and speed"*. In line with that, Teng *et al*., (1994) describes BPR as a technique for critical analysis and radical redesign of prevailing business processes to obtain great improvements in performance measures. Similarly, Patwardhan A., and Patwardhan (2008) has viewed BPR as discrete initiatives undertaken to drastically redesign and improve the work processes within a specific period. Thus, it is clear that the main intention of BPR is to entirely reinvent the business processes to achieve greater improvements. However, through the literature, three different forms of BPR can be identified: namely process improvement (i.e. use conservative approaches to make incremental improvements); evolutionary BPR (i.e. use incremental approaches to attain radical improvements); and revolutionary BPR (i.e. use clean slate approach to achieve radical and dramatic business improvements) (Lu and Yeh, 1998).

Since reengineering is all about organizing work, it can be applied to any organisation in which work is performed, whether it is a multi-billion company or a small company, and whether it belongs to public or private sector (Hammer and Champy, 1993). As per Redlein (2005), BPR can be used for any process: i.e. both core and/ or non-core processes; within every industry extending from production processes to office automation. Zygiaris (2000) revealed that BPR could be implemented in any organisation which consists of minimum twenty employees and possesses a strong management commitment to new ways of working, and a well-formed IT infrastructure. In recent past, BPR projects have become the driving forces of organisational change within the service sector, both in private and public organisations, to address and meet new challenges, particularly those related to the service quality (Jetu and Reidl, 2013). Similarly, Currie (1999) declared that several companies in the developed countries which were about to collapse have managed to sustain themselves in the market by means of adopting BPR.

3. IMPLEMENTATION PROCESS OF BPR PROJECTS

Since the real success of BPR depends on implementation (Clegg, 2000), organisations should be highly concerned with the approaches for implementing BPR projects and process for implementing BPR projects. Review of literature disclosed that, though the reengineering efforts can be executed entirely by the in-house teams, most of the BPR efforts had external assistance from the consultants (Crowe *et al*., 2002). Akhavan *et al*., (2006) has further emphasised it by stating that the use of outside consulting firms for reengineering is one of the most popular trends.

Various structured-based methodologies have been suggested for BPR implementation by different authors (Hammer and Champy, 1993; Hesson *et al*., 2007). However, a review of these different BPR approaches and methodologies revealed that, most pursue a path which is almost similar with recurring themes in main areas (Vakola *et al*., 2000). A typical BPR procedure can be seen to comprise typically of five steps: namely, preparing for reengineering; mapping and analysing the AS IS process (i.e. current process); design the TO BE process (i.e. new redesigned process); implement the reengineered process; and improving continuously (Hammer and Champy, 1993; Muthu *et al*., 2006). Via careful analysis, it is possible to categorize and organize the above stated steps into three BPR implementation phases i.e. Pre-BPR implementation phase, BPR implementation phase, and Post-BPR implementation phase, as identified by Radhakrishnan and Balasubramanian (2008).

Pre-BPR implementation phase of BPR projects covers envisioning (planning), initiating (establishing steering teams, select projects and teams), and diagnosing (mapping and analysing existing processes) (Emerie-Kassahun and Molla, 2013). Thus, this phase accommodates BPR implementation steps such as 'preparing for reengineering' and 'mapping and analysing the AS IS processes'. Based upon the mapping of AS IS processes, the critical process to be investigated and redesigned needs to be identified (Rinaldi, *et al*., 2015).

As per Emerie-Kassahun and Molla (2013), BPR implementation phase include redesigning processes, prototyping, implementing and managing the redesigned processes. Hence it can be realized that the main steps coming under this phase are 'design of the TO BE processes' and 'implement the reengineered processes'. Emerie-Kassahun and Molla (2013) has further stated that the post-BPR implementation phase involves on-going activity of process adaptation, acceptance, routinization, alignment of IS with the information needs of the redesigned processes, and management support system. This, makes it clear that 'improving continuously' is the step coming under post-BPR implementation phase.

Hence, it is clear that the BPR implementation process is a consecutive process with five key steps which should be performed properly to ensure the project success. In order to ensure the successful performance of such key steps in a BPR process, certain key reengineering roles need to be present.

4. KEY REENGINEERING ROLES FOR SUCCESSFUL IMPLEMENTATION OF BPR PROJECTS

Since reengineering projects tend to be larger, longer, and more exacting, than initially anticipated, there will be numerous stakeholders behind these projects (Ulbrich, 2006). There are certain roles that emerge during the implementation of BPR such as leader, process owner, reengineering team, team captain, steering committee, and reengineering czar (Bradley, 1994; Hammer and Champy, 1993). Each role has certain functions to be performed throughout the reengineering project and those roles have been identified by Hammer and Champy (1993). Table 1 summarises these key reengineering roles which are essential for successful BPR implementation together with their functions.

Table 1: Reengineering Roles and their Key Functions for the Successful Implementation of BPR Projects

Reengineering roles	Key functions
Leader	Act as visionary and motivator Appoints senior managers as owners of business processes Create an environment conductive to reengineering i.e. supporting others to perform Have authority over the resources involved in performing processes
Process owner	Responsible for reengineering a specific process Ensure that the BPR results are achieved Assemble a BPR team and do whatever required to enable the team to do its job Motivate, inspire and advise BPR teams Act as the teams’ critic, spokesperson, monitor and liaison Creates and maintains strategic relationships with the Project Board and key stakeholder groups
Reengineering team	Reinvent the business i.e. produce the ideas and plans and turn them into reality Act as key change agents when new process is going to be put in place (Insiders) Act as imaginative thinkers i.e. envisioning a concept and making it happen (Outsiders) Should go through an interactive learning process to invent a new way of performing work
Team captain	Act as a team member and enable the team members to do their work

Reengineering roles	Key functions
	Establish agenda for team meetings and help team to stick to it Mediate conflicts between team members
Steering committee	Decides the order of priority among all the competing reengineering projects Make decisions with respect to resource allocation Hear and resolve conflicts among process owners
Reengineering czar	Serves as the leader's chief of staff for reengineering Enabling and supporting each individual process owner and reengineering team Coordinating all ongoing BPR activities Help select insiders for the team and identify and provide appropriate outsiders Advise new process owners on the issues and problems that are likely to encounter Keeps a watchful eye on the process owners to keep them on track Convene and moderate some discussions among the process owners Make sure the coordination among the process owners Concern with developing the infrastructure for reengineering Anticipate infrastructural needs and meet them even before they arise

Source: (Adapted from Hammer and Champy, 1993)

From the review of literature, it was clear that only a few authors have focuse on identifying reengineering roles and that there is a general lack of literature related to this area. Moreover, no attempt has been made so far to look at the reengineering roles that should be involved in different phases of BPR projects. Thus, a relative void in literature exists with respect to key reengineering roles which needs to be addressed. This further reinforces the vitality of this study.

5. RESEARCH METHODOLOGY

The aim of this research is to identify the key reengineering roles for the successful implementation of BPR projects. Thus, a qualitative research approach was adopted as it facilitates to achieve the aim by providing a deeper understanding of the area being investigated. Among the available qualitative research strategies, 'case study' approach was selected for this study as it allows the investigation of a modern phenomenon within its real-life context (Yin, 2009) and thus helping to gain an in-depth understanding of the problem being investigated (Morris and Wood, 1991).

Four cases were selected to conduct an in-depth analysis within the limited time frame. Due to difficulties in collecting data, selection of cases was limited to organisations in the Western province of Sri Lanka. Further, this study was intended to acquire responses from well reputed organisations who have good experience in the field of BPR so that the best practices in the industry could be well captured. Figure 1 depicts the criteria used for selection of cases.

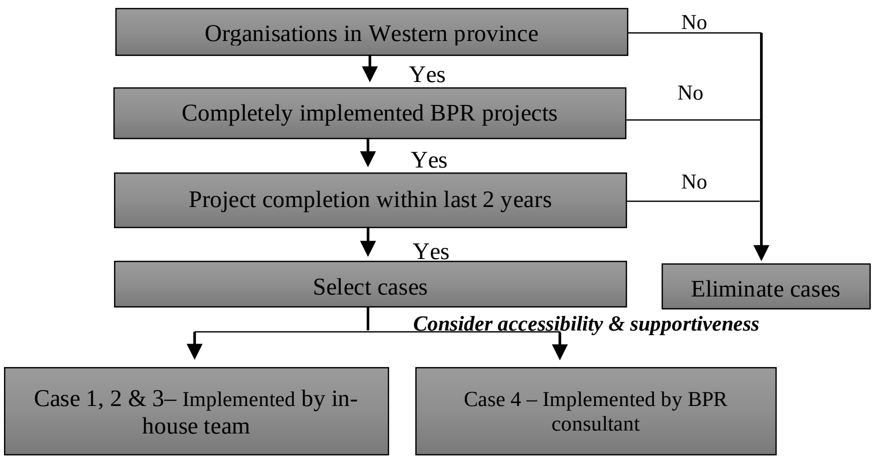

Figure 1: Criteria for Case Selection

As depicted in Figure 1, the selected reengineering projects from all the four cases have been undertaken within last two years and have reached full implementation by the time of study. Organisations can reengineer their business processes either with the assistance of in-house BPR team or with the assistance of BPR consultants (Refer section 3). Therefore, in order to replicate this true nature of BPR implementation within the data collection process, it was decided to select both types of cases. In addition, in case selection concern was given towards selecting cases to represent both core and non-core process related reengineering efforts as discussed in section 2. Table 2 provides a brief description of the selected cases.

Table 2: Case Description

Case	Reengineered by	Reengineered process	Business sector	Selected reengineering process	Form of BPR	Duration (months)
A	In-house BPR team	Core process	Apparel industry	One of the production lines was reengineered by introducing automatic machines to reduce the process delays	Process improvement	18
B	In-house BPR team	Core process	Apparel industry	A production process was reengineered by isolating certain components from the process along with introducing automated machines to attain greater improvements	Revolutionary BPR	8
C	In-house BPR team	Core and non-core process	Telecommunication sector	All the processes relating to a particular product was reengineered via incremental steps to achieve radical improvements	Evolutionary BPR	6
D	BPR consultant	Core and non-core process	Manufacturing sector	All the processes in the factory was reengineered completely to attain radical and dramatic improvements	Revolutionary BPR	7

In total fourteen (14) semi-structured interviews were carried out with the key stakeholders in the reengineering projects of the selected organisations for the purpose of collecting the relevant data. The content analysis has been used as data analysis technique in this study. Among the data analysis software to support the content analysis, this study has selected QSR. NVivo (2011) software to capture the findings from the interview transcripts and for effective interpretation of the data.

6. CASE STUDY FINDINGS

Since literature has failed to provide a path to identify the key reengineering roles which may get involved in different phases of the BPR project, in this study an attempt was made to identify the key reengineering roles that may get involved in all the three phases of a reengineering project. The reengineering roles get involved in different phases of the BPR project will be discussed in the following sections.

6.1. KEY REENGINEERING ROLES IN PRE-BPR IMPLEMENTATION PHASE

Through the case study analysis, a total of eight (8) reengineering roles, which are involved in Pre-BPR implementation phase have been ascertained together with their key functions. Respondents’ responses on various reengineering roles involved in the Pre-BPR implementation phase along with their functions are shown in Table 3.

From Table 3 it is vivid that, among the reengineering roles involved in Pre-BPR implementation phase, the role of ‘initiator’ and ‘reengineering facilitators’ are not being specified by the respondents from Case C. When considering the key functions performed by each reengineering role in Pre-BPR implementation phase, ‘Selection of appropriate insiders for the BPR project’ is the key function to be performed in the Pre-BPR implementation phase and being highlighted by all the 14 respondents. In addition, ‘assembling the reengineering team’, ‘make decisions with respect to resource allocation’, ‘predict required resources and infrastructure for the project', 'coordinate all the reengineering activities' are being specified by most of the respondents from all the four cases as vital functions to be performed in this phase and emphasised by 13 out of 14 respondents.

Table 3: Responses on the Reengineering Roles Involved in Pre- BPR implementation Phase and their Functions

Reengineering roles	**Key functions performed**	**Cases**				**Total**
		A	**B**	**C**	**D**	
Pre-BPR implementation phase						
Initiator	Initiate the project	2/3	2/4		3/3	7/14
	Appoint a leader for the project	2/3				2/14
	Review the project status periodically	2/3				2/14
Leader	Appoint a senior manager as the process owner			4/4	2/3	6/14
	Assign the reengineering czar	2/3	2/4	2/4	2/3	8/14
	Create objectives for the BPR effort		3/4			3/14
	Approve the project proposal		4/4		1/3	5/14
	Induce others to translate the objectives into reality		2/4	2/4		4/14
	Review the project performance and status time to time			4/4		4/14
Process owner	Assemble the reengineering team and enable the team to do its job	3/3	3/4	4/4	3/3	13/14
	Motivate, inspire and advise the reengineering team	3/3	1/4	2/4	2/3	8/14
	Created and maintained strategic relationship with the key stakeholders	3/3	3/4	4/4	1/3	11/14
Reengineering team	Discover and evaluate reengineering opportunities				3/3	3/14
	Review and map the existing processes		4/4		3/3	7/14
	Identify the inefficiencies in the existing processes		3/4	1/4	3/3	7/14
	Evaluate the feasibility of each option	2/3	2/4	1/4		5/14
	Determine project scope				2/3	2/14
	Gather the requests made for reengineering			2/4		2/14
	Determine the tasks that can be automated			4/4		4/14
	Produce ideas for re-design	3/3	3/4	4/4	2/3	12/14
	Design the new process		2/4	4/4	2/3	8/14
	Develop the project proposal	2/3				2/14
	Prepare prototype		4/4			4/14
	Communicate the changes to the customers		3/4			3/14
	Define the methodology for the project				2/3	2/14
Team captain	Establish agenda for team meetings	3/3	1/4	3/4	3/3	10/14
	Mediate conflicts between the team members	2/3	1/4	1/4	3/3	7/14
	Enable the team members to do their works			4/4		4/14
Steering committee	Decide the order of priority among all the competing projects	3/3	4/4	1/4	3/3	11/14
	Make decisions with respect to resource allocation	3/3	4/4	3/4	3/3	13/14
Reengineering czar	Select insiders for the reengineering project	3/3	4/4	4/4	3/3	14/14
	Predict required resources and infrastructure for this project	2/3	4/4	4/4	3/3	13/14
	Coordinate all the reengineering activities in this phase	3/3	3/4	4/4	3/3	13/14

	Monitor the activities done by the process owner		3/4			3/14
	Advise the process owner on the issues that are likely to encounter		1/4		3/4	4/14
	Make the leader aware of the project status time to time				2/4	2/14
Reengineering facilitators	Identify the inefficiencies in the processes and raise the need for reengineering	3/3				3/14
	Approve the project proposals	2/3			3/3	5/14
	Assist to assess the operational requirement	3/3	1/4			4/14
	Upgrade the IT infrastructure for this project				3/4	3/14

Moreover, since the ‘reengineering team’ has many key functions to be performed in the Pre-BPR implementation phase, ‘assembling the reengineering team and enable the team to do its job’ and ‘selecting appropriate insiders for reengineering project’ can be concerned as crucial functions to be performed in Pre-BPR implementation phase. This is almost in line with the respondents’ responses on the vital key functions to be performed in this phase.

6.2. *KEY REENGINEERING ROLES IN BPR IMPLEMENTATION PHASE*

Outcomes of the interview revealed in total seven (7) key reengineering roles involved in the BPR implementation phase together with their key functions. Among such key functions, nine (9) functions are mentioned by the respondents from all the four cases and thereby insist the cruciality of the performance of such functions in the BPR implementation phase. Table 4 depicts the respondents’ responses with respect to the key reengineering roles to be involved in BPR implementation phase along with their key functions.

Table 4: Responses on the Reengineering Roles Involved in BPR Implementation Phase and their Functions

Reengineering roles	**Key functions performed**	**Cases**				**Total**
		A	**B**	**C**	**D**	
BPR implementation phase						
Leader	Create an environment conductive to reengineering	3/3	4/4	3/4	3/3	13/14
Process owner	Motivate, inspire and advice BPR team	2/3	1/4	1/4	3/3	7/14
	Enable the team to do its job				2/3	2/14
	Maintain strategic relationship with the key stakeholder groups	2/3	3/4	1/4	3/3	9/14
	Make the steering committee aware of the project status			2/4		2/14
Reengineering team	Test the prototype	1/3				1/14
	Implement the reengineered process	3/3	4/4	3/4	3/3	13/14
	Communicate changes to the stakeholders and convince them	3/3	4/4	4/4	2/3	13/14
	Determine the impact caused by the project to the way of work		1/4	3/4		4/14
	Managing change	2/3	2/4	4/4	1/3	9/14
Team captain	Establish agenda for team meetings	2/3	1/4	3/4	2/3	8/14
	Mediate conflicts between team members	2/3	1/4	4/4	2/3	9/14
	Enable the team members to do their works		3/4		1/3	4/14
Steering committee	Make decisions with respect to resource allocation		4/4	1/4	3/3	8/14
Reengineering czar	Coordinate all the reengineering activities in this phase	3/3	4/4	4/4	3/3	14/14

	Monitor the activities done by the process owner				3/3	3/14
	Convene and moderate some discussions with the process owner	2/3	3/4			5/14
	Advise the process owners on the issues or problems that are likely to encounter	3/3	4/4		2/3	9/14
	Enable and support the process owners and reengineering team		4/4	2/4	1/3	7/14
	Make the leader or steering committee aware of the project status time to time				3/3	3/14
	Ensure the availability of needed infrastructure facilities when needed			1/4		1/14
Reengineering facilitators	Released the project stakeholders from their functional roles	1/3	4/4		3/3	8/14
	Provide IT support for the new process			1/4		1/14
	Assisted in recruiting new employees	2/3	4/4			6/14
	Facilitate in successful implementation of new process	3/3		1/4		4/14

In this phase, all the respondents from all the four cases have declared that 'coordinating all the reengineering activities' is the decisive task to be performed. Additionally, 'creating an environment conductive to reengineering', 'implementing the reengineered process properly' and 'communicating the changes to the stakeholders and convincing them' are also being disclosed by the respondents from all the four cases as critical functions to be performed and highlighted by 13 out of 14 respondents. Hence, proper performance of these key functions by the respective stakeholders can be concerned as the major step towards the project success.

6.3. *KEY REENGINEERING ROLES IN POST-BPR IMPLEMENTATION PHASE*

Through case study analysis, altogether five (5) reengineering roles were identified to be involved in Post-BPR implementation phase. Among such roles, the role of 'team captain' is specified only by the respondents from Case C. Conversely, the role of 'steering committee' and 'reengineering czar' were disclosed by all the three cases except Case C. Table 5 exhibits the respondents' responses on reengineering roles and their functions in Post-BPR implementation phase.

Table 5: Responses on the Reengineering Roles Involved in Post- BPR Implementation Phase and their Functions

Reengineering roles	**Key functions performed**	**Cases**				**Total**
		A	**B**	**C**	**D**	
Post-BPR implementation phase						
Process owner	Ensure that the BPR results are achieved	2/3	3/4	2/4		7/14
	Continuously improve the reengineering process by monitoring and measuring the reengineered process		4/4	4/4	2/3	10/14
	Maintain strategic relationship with the key stakeholder group		3/4	4/4	2/3	9/14
	Communicate the project status time to time to the steering committee			3/4		3/14
Team captain	Conduct awareness programmes			4/4		4/14
Steering committee	Make decisions with respect to resource allocation	2/3	2/4		2/3	6/14
Reengineering czar	Advise the process owners on the issues or problems that are likely to encounter	2/3	3/4		1/3	6/14
	Monitor the activities done by the process owner		1/4			1/14

Reengineering facilitators	Contribute in successfully operating the reengineered process	3/3		1/4		4/14
	Establish a new reward system	2/3	4/4		3/3	9/14
	Identify the inefficiencies in the new process	3/3	3/4	1/4	3/3	10/14
	Make requests to improve the new process		3/4		3/3	6/14
	Measure and evaluate the effectiveness of changes			4/4		4/14
	Check the effectiveness of IT infrastructure periodically			4/4		4/14

Among the functions to be performed in this phase, ‘identifying the inefficiencies in the new process’ and ‘continuously improving the reengineering process by monitoring and measuring the reengineered process’ were the key functions emphasised by 10 out of 14 respondents. However, ‘identifying the inefficiencies in the new process’ was divulged from all the four cases whereas ‘continuously improving the reengineering process by monitoring and measuring the reengineered process’ was specified by the respondents from only three cases i.e. Cases B, C, and D. In addition, ‘maintaining strategic relationship with the key stakeholder group’ and ‘establishing a new reward system’ were also being mentioned by the respondents as vital functions to be performed in this phase.

7. DISCUSSION

Overall, in addition to the reengineering roles identified from the literature, from the case studies two more roles named as ‘initiator’ and ‘reengineering facilitators’ were identified. From the selected cases, the role of initiator is mainly being highlighted in Case A. In Case A, the persons who performed the roles of initiator and leader were different whereas in the Cases B and D, the same person has performed the roles of initiator and leader. However, in Case C no single person played the role of initiator, and their Governance Board (i.e. steering committee), only made decisions with respect to the initiation of BPR projects based upon the suggestions made by the business users or customers.

When considering the key functions identified through the literature review and case studies, some of the functions are in line with the literature whereas some are truly elicited from the case studies. Among the key functions to be performed by the leader, ‘assign the reengineering czar’, ‘approve the project proposal’, and ‘review the project performance and status time to time’ are the functions purely identified through the case studies. Similarly, among the functions to be performed by the process owner ‘make the steering committee aware of the project status’ and ‘communicate the project status time to time’ are ascertained through respondents’ responses and were not disclosed from the existing literature. Conversely, Hammer and Champy (1993) has identified ‘acting as a team’s critic, spokesperson, monitor and liaison’ as one of the functions to be performed by the process owner, but it was not disclosed from the case study findings.

Among the functions of the reengineering team elicited through the case studies, most of the functions are purely discovered through case studies i.e. ‘discover and evaluate reengineering opportunities’, ‘review and map the existing processes’, ‘identify the inefficiencies in the existing processes’, ‘evaluate the feasibility of each option’, ‘determine project scope’, ‘gather the requests made for reengineering’, ‘determine the tasks that can be automated’ ‘develop the project proposal’, ‘prepare prototype’, ‘define the methodology for the project’, ‘test the prototype’, and ‘determine the impact caused by the project to the way of work’. Comparably, when referring to the functions of the team captain, ‘conducting awareness programmes’ is the one only function ascertained in addition to the literature findings. Conversely, the functions of the steering committee identified through case studies are in line with the literature findings. However, in addition to the functions of the reengineering czar identified through literature, case study analysis revealed an added function i.e. ‘make the leader or steering committee aware of the project status time to time’.

Further, based upon the respondents’ responses it has been ascertained that reengineering roles involved in Pre-BPR implementation phase and BPR implementation phase are almost same except the role of initiator. However, the functions being performed by each role is different from phase to phase. Moreover, from the case studies an immense knowledge is gained on reengineering roles and relationship among each role based upon which the following diagram is being developed. Figure 1 illustrate the interactions among the reengineering roles.

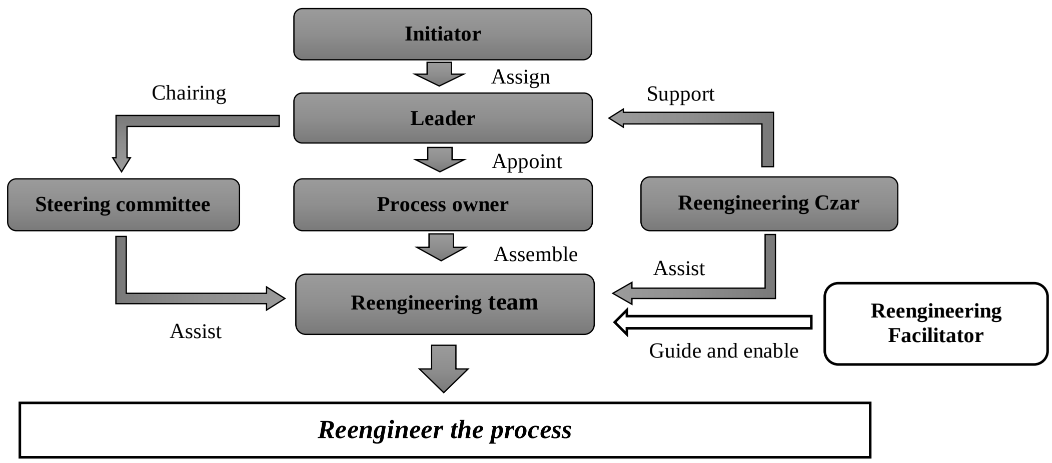

Figure 1: Interaction Among the Reengineering Roles

As shown in Figure 1, in each case the reengineering team was responsible for reengineering the selected process, whereas other stakeholders provided their assistance and support to the reengineering team members to successfully proceed with the project. The reengineering facilitator is most probably an independent resource within the organisation who enable and support the reengineering team to perform its duties properly whereas the rest of the stakeholders are part of the BPR project.

8. CONCLUSIONS

BPR is about radical redesign of business processes to achieve tremendous improvements in certain critical areas. Though BPR offers many benefits to the organisation, in most instances efforts of BPR has proved abortive. Reviewing of literature related to BPR has revealed that only few authors have given sufficient concern towards identifying the key reengineering roles to be involved throughout the BPR projects. Moreover, no any directions were provided in literature to identify the reengineering roles to be involved in each phase together with their key functions. Thus, in this study an attempt was made to identify the reengineering roles to be involved in each phase of the BPR projects together with their functions.

A qualitative research approach was adopted in this study, in which case study was selected as the research strategy. In total four (4) case studies were conducted among the organisations in the Western Province of Sri Lanka who have completely implemented BPR projects within last two years.

Through the case study findings in total eight (8) reengineering roles (i.e. initiator, leader, process owner, reengineering team, team captain, steering committee, and reengineering czar) were discovered along with their functions. Among the identified roles, the role of ‘initiator’ and ‘reengineering facilitators’ were truly elicited from the case studies and not disclosed via the existing literature, whereas rest of the six roles are in line with the roles identified by Hammer and Champy (1993). Further, the analysis revealed that there are substantial differences between the key functions of each reengineering role identified through the literature and case studies (refer section 7). Moreover, via the case studies reengineering roles and interaction among such roles has also been ascertained. As a whole, it is expected that the findings of this paper with respect to the key reengineering roles that should be involved in each phase of BPR projects along with their functions will help organisations to assure the successful implementation of BPR projects.

9. REFERENCES

Ahmed, P. K. and Simintiras, A. C., 1996. Conceptualizing business process re-engineering. *Business Process Management Journal, 2*(2), 73-92.

Akhavan, P., Jafari, M. and Ali-Ahmadi, A.R., 2006. Exploring the interdependency between reengineering and information technology by developing a conceptual model. *Business Process Management Journal, 12*(4), pp.517-534.

Alas, R., Zernand-Vilson, M. and Vadi, M., 2012. Management Techniques in Estonian Organizations: Learning Organization and Business Process Reengineering. *Procedia - Social and Behavioral Sciences*, *62*, 494-498.

Atkin, B. and Björk, B., 2007. Understanding the context for best practice facilities management from the client's perspective. *Facilities*, *25*(13/14), 479-492.

Bradley, S., 1994. *Creating and adhering to a BPR methodology*. Gartner Group Report, Springler, pp.1-30.

Campbell, S. and Kleiner, B.H., 2001. New developments in re-engineering organisations. *Management Research Review, 24*(3/4), p.5.

Clegg, D., 2000. *Applying the designer/2000 process modeller for Business Process Reengineering*. MA: Oracle Corporation.

Crowe, T.J., Meghan Fong, P., Bauman, T.A. and Zayas-Castro, J.L., 2002. Quantitative risk level estimation of business process reengineering efforts. *Business Process Management Journal, 8*(5), pp.490-511.

Currie, W. L., 1999. Revisiting management innovation and change programmes: strategic vision or tunnel vision? *Omega*, *27*(6), 647-660.

Drago, W. and Geisler, E., 1997. Business process re-engineering: lessons from the past. *Industrial Management & Data Systems*, *97*(8), 297-303.

Emerie-Kassahun, A. and Molla, A., 2013. BPR complementary competence: Definition, model and measurement. *Business Process Management Journal*, *19*(3), 575-596.

Hammer, M. and Champy, J., 1993. *Reengineering the Corporation: A Manifesto for Business Revolution*. New York, NY: Harper Business.

Hesson, M., Al-Ameed, H. and Samaka, M., 2007. Business process reengineering in UAE public sector: a town planning case study. *Business Process Management Journal*, *13*(3), 348-378.

Jackson, N., 1997. BPR'96-A report on the Business Process Re-engineering conference organised by Business Intellegence and held at the end of October in London. *Management Services, 41*(2), pp.34-37.

Jetu, F. T. and Riedl, R., 2013. Cultural values influencing project team success. *International Journal of Managing Projects in Business*, *6*(3), 425-456.

Khodambashi, S., 2013. Business process re-engineering application in healthcare in a relation to health information systems. *Procedia Technology*, *9*, pp.949-957.

Lu, H.P. and Yeh, D.C., 1998. Enterprises' perceptions on business process re-engineering: A path analytic model. *Omega*, *26*(1), pp.17-27.

Morris, T., and Wood, S., 1991. Testing the survey method: Continuity and change in British industrial relations. *Work, Employment & Society*, *5*(2), 259-282.

Muthu, S., Whitman, L. and Cheraghi, S. H., 2006. Business process reengineering: a consolidated methodology. In *Proceedings of the 4th Annual International Conference on Industrial Engineering Theory, Applications and Practice, 1999 US Department of the Interior-Enterprise Architecture*. November 17–20, 1999, San Antonio, Texas

Patwardhan, A. and Patwardhan, D., 2008. Business process re-engineering – saviour or just another fad? *International Journal of Health Care Quality Assurance*, *21*(3), 289-296.

Radhakrishnan, R., and Balasubramanian, S., 2008. *Business process reengineering: Text and cases*. New Delhi: Phi Learning.

Redlein, A., 2005. *Change management within FM*. na.

Rinaldi, M., Montanari, R. and Bottani, E., 2015. Improving the efficiency of public administrations through business process reengineering and simulation. *Business Process Management Journal*, *21*(2), 419-462.

Ryan, S. and Hurley, J., 2004. Have Total Quality Management, Business Process Re-Engineering and the Learning Organisation been replaced by Knowledge Management? *Irish Journal of Management*, *25*(1), 41-55.

Schniederjans, M.J. and Kim, G.C., 2003. Implementing enterprise resource planning systems with total quality control and business process reengineering: survey results. *International Journal of Operations & Production Management*, *23*(4), pp.418-429.

Teng, J.T., Grover, V. and Fiedler, K.D., 1994. Business process reengineering: charting a strategic path for the information age. *California Management Review*, *36*(3), pp.9-31.

Tennant, C. and Wu, Y., 2005. The application of business process reengineering in the UK. *The TQM Magazine*, *17*(6), 537-545.

Ulbrich, F., 2006. Improving shared service implementation: adopting lessons from the BPR movement. *Business Process Management Journal*, *12*(2), 191-205.

Vakola, M., Rezgui, Y. and Wood-Harper, T., 2000. The Condor business process re-engineering model. *Managerial Auditing Journal*, *15*(1/2), 42-46.

Yin, R. K., 2009. *Case study research: Design and methods* (4th ed.). New York, NY: Sage Publications.

Zygiaris, S., 2000. Business Process Reengineering (BPR): Report produced for the EC funded project. *INNOREGIO: dissemination of innovation and knowledge management techniques, HELLAS SA.* [Available from: http://www.adi.pt/docs/innoregio_BPR-en.pdf] .

NATURE OF EXISTENCE OF PUBLIC SECTOR CONSTRUCTION PROJECT CULTURE: AN EXPLORATORY CASE STUDY

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ABSTRACT

Cultural differences cause conflicts among construction project participants, deterring success of the project. Thus, understanding the nature of existence of construction project culture can assist in achieving better project management. An exploratory case study was adopted to develop propositions with this regard for further research purposes. The research was limited to study the culture of a public sector building construction project. Semi-structured interviews with nine key project participants and observation of two progress review meetings were used as the data collection techniques. As per the research findings, construction projects being temporary organisations, culture was basically emerged focusing on clearly defined project objectives. In addition, construction project culture could be emerged and transferred through continuous interactions and socialisations with the time. Thus, time became a concern for proper internalisation of the cultural aspects. Project members at high authority levels contributed more for emergence and transfer of cultural aspects. Shared behavioural norms were not much popular in the studied project culture. Highly differentiated professional sub-cultures such as; client, contractor and consultant were available. Fragmented behavioural norms were identified creating conflicting and paradoxical situations within the project. These findings can be further confirmed by replication in multiple case studies.

Keywords: *Behavioural Norms; Construction Project Culture; Culture Emergence; Fragmentation; Sub-Cultures.*

1. INTRODUCTION

The construction industry has its run through different human interactions along the design and construction phases of a construction product. Hence, behaviour of each and every individual within a project is significant to its success. ‘Culture’ becomes a major factor owing to the behavioural differences among these individuals, which requires proper attention by the management (Tijhuis, 2011). Cicmil and Gaggiotti (2014) criticise the slippery use of culture in project management practices and highlight the necessity of learning culture as a context-dependent social relational practice.

The early elaboration of organisational culture as ‘the way we do things around here’ by Bower (1966, p.22) provides a simple, but, a powerful definition on culture focusing on behavioural manifestations. Zuo and Zillante (2005) describe construction project culture as shared beliefs, values and basic assumptions, which determine the way the project is processed and the nature of relationships to be built up among members. All these definitions on culture attempt to use different manifestations such as; behaviours, practices, beliefs, values, basic assumptions to describe culture. Further, it is apparent that the use of the term ‘shared’ (Zuo and

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Zillane, 2005) is to indicate culture as unifying and integrated phenomenon among the members in the construction project cultural context. Despite of a dominantly shared culture, Kumaraswamy *et al*. (2002) highlight that construction project culture consists of several sub-cultures. Further, according to Gajendran *et al*. (2012), there could be ambiguities and paradoxes in meanings created by cultural manifestations, contributing to construction project culture, which are mostly disregarded by many researchers.

Above discussed theoretical aspects create doubts on the nature of existence of project culture in construction context. Thus, the aim of this paper is to bring in empirical evidences on how construction project culture exists, in order to build up propositions for further research. The findings of this paper is based on a public sector project.

2. NATURE OF EXISTENCE OF CONSTRUCTION PROJECT CULTURE

Construction projects constitute of members from different organisations working together for a specific period of time and considered as temporary multiple organisations (Fellows *et al*., 2007). Construction project organisations hold the characteristics of short life organisations, which are operating for a specific purpose and specific time duration (Ankrah *et al*., 2005).

Meudell and Gadd (1994) elaborate that it is in 'long-run organisations' that believe culture should be gradually developed and transformed consuming long durations and gradually build up on the history created within the organisation. However, 'short life organisations', such as project organisations, which are with a specific purpose and time duration, should develop a culture by focusing on a clearly defined mission. Such cultures mostly do not acquire histories generating myths, rituals, rites and so on. Further, Schein (1983) mentions that culture will not develop and embed until the members start surviving by overcoming different crisis and critical situations within such a cultural context.

Schein (1983) and Marrewijk (2007) highlight the contribution of higher authority level members can make in creating a specific culture. Marrewijk (2007) brings in empirical evidence from a mega development project, which had clearly visible two cultural episodes called 'Gideon's Gang' and 'Diplomats', solely due to the management style of the higher project management. More importantly, Schein (1983) stresses that group leader tends to shape up culture using his/her personality.

The culture could get transferred when new members join the setting. Hence, transfer of culture is defined within this paper as the actions of familiarising and inculcating the existing cultural aspects by newcomers. Ashforth and Mael (1989) describe that 'social identification' of a member is about referring oneself to a social category, while 'internalisation' is about incorporating or believing the values, attitudes and other cultural aspects of the social entity to oneself as guiding principles. Thus, transferring culture to a new member has to be about internalising the cultural aspects. According to Schein (1984), for a cultural aspect in an organisation to be passed on to newcomers, such cultural aspects should have helped solving problems in organisational environment. Existing members of the organisation should have received proven results by having such artefact, practices, values or basic assumptions. In order to pass them to the newcomers as valid cultural features, which are worth being adopted. However, the question is 'can such an established culture exist in construction project context?' In order to search answers to this question, it is worth looking at the ways project culture is explained by researchers.

Different manifestations are used by different researchers to describe a cultural context. This exhaustive list of manifestations includes, but not limited to; symbols, stories, rites, rituals, customs, relationships; behaviours, norms, attitudes, values, basic assumptions (Hofstede, 2001; Martin, 2004; Zuo, 2008; Gajendran *et al*., 2012). Martin (2004) states that it is misleading and too simple if a researcher tries to elaborate a cultural context only using one of the manifestations. Kappos and Rivard (2007) group these cultural manifestations as; cultural forms, practices including both formal and informal practices and content themes. In addition, Schein (2004, 1990, 1984) describes that these 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 organizational culture. According to Schein (2004), manifestations at higher levels provide better interpretations of culture.

Further, Martin (2004) explains that culture in a given group is the patterns of meanings that link the aforementioned manifestations together; some in harmony as shared meanings (integration perspective), some shared only in sub-groups (differentiation perspective) and some in mere paradox and conflicts (fragmentation perspective). Thus, Martin (2004, 2002) strongly criticised the attempts in cultural research trying to describe culture only using the integration perspective on culture.

However, many researchers in construction project cultural research has used the integrated perspective or the shared view on culture. For example, Zuo (2008) has carried out a research study on project culture in Australian and Chinese construction industries. According to Zuo's (2008) proposed project cultural model, construction project culture consists of five dimensions as; Integrative, Cooperative, Goal-oriented, Flexible and People-oriented.

Some studies on construction project culture are based on the differentiation perspective highlighting the effect of different subcultures on project culture. These sub-cultures are mostly based on national, industry, organisational and professional cultures. Ankrah and Langford (2005), who studied on architectural and contracting organisations, explain that major differences exist in these two organisation types not only in its structure but also in issues related to people. Hence, it is apparent that organisational and professional cultures have an impact on the construction project culture. Further, Kumaraswamy *et al*. (2002) elaborate that ‘organisational’, ‘professional’, ‘operational’ and ‘individualistic’ sub-cultures as the principal elements that come together to evolve the culture within a construction project. Further to authors, a number of components contribute to each sub-culture, where one or more sub-cultures may dominate, depending on their ‘relative strengths’. However, this model has not yet been empirically proven.

Different researchers have used fragmentation perspective for elaborating culture in different industrial contexts such as in retail (Harris and Ogbonna, 1998) and information technology (Kappos and Rivard, 2007). Gajendran *et al*. (2012) too highlight the possibility and advantages of researching the fragmentation perspective in construction project culture to understand conflicts and ambiguities within construction projects. However, there is dearth of literature in construction research arena, which incorporates construction project culture using all three perspectives (i.e. integration, differentiation and fragmentation), which would be observed empirically in this research. The next section elaborates the methodology of this study. Above discussed theoretical aspects create doubts on the nature of existence of project culture in construction context. Thus, the aim of this paper is to bring in empirical evidences on how construction project culture exists, in order to build up propositions for further research. The findings of this paper is based on a public sector project.

3. METHODOLOGY

The aim of this study is to explore the context of construction project culture in public sector projects and develop propositions for further study. Thus, exploratory case study was selected as the research strategy of this research. A single case was selected as a ‘critical case’ in a manner of theory testing. As elaborated by Yin (2009, p.47); “A single case, meeting all of the conditions for testing the theory, can confirm, challenge, or extend the theory. The single case can then be used to determine whether a theory’s propositions are correct or whether some alternative set of explanations might be more relevant”. The selected case to be a critical case, it had a project team set up with a contractor who had previous working experience with the consulting organisation and the client was new to both the contractor and the consultant.

Unit of analysis was the construction project culture. A public sector building construction project in Sri Lanka was selected as the case. Data collection techniques included; nine semi structured interviews and observation of two progress review meetings. Interviewees included; three members from the client’s representatives [Deputy Director (Corporate Management), Technical Officer (Maintenance), Procurement Assistant], three members from consultant’s representatives (Project Manager, Project Architect, Project Quantity Surveyor) and three members from contractor’s perspective (Construction Manager, Site Engineer, Project Quantity Surveyor).

According to Schein (1983; 1984), patterns of underlying basic assumptions of a cultural context could be realized through analysing the reactions, behaviours and solutions bring forward by the group members for internal integration problems (language, boundaries, power and status, intimacy, rewards and punishments and ideology) and external adaptation problems (strategy, goals, means of accomplishing goals, measuring performance and corrections) of the group. Thus, the interview guideline and progress review meeting observation guideline consisted of questions inquiring and observing behaviours and solutions to internal integration problems and external adaptation problems to capture the behavioural norms and basic assumptions of the project team members. However, as this paper is part of a bigger research study on unearthing basic assumptions of construction project culture in Sri Lanka, detailed procedure of analysing basic assumptions would not be presented.

4. CASE STUDY FINDINGS

The empirical study was conducted using a six-storied government office building construction project (Project XYZ) for a ministry, procured under traditional procurement method with measure and pay contract. The project team consisted of a government consultancy organisation and a private contractor organisation. Construction contract sum of the project was Sri Lankan rupees 1317 million and duration was 21 months. The physical construction progress was 65% by the time of data collection.

Project XYZ indicated some evidence on how contractor and consultant believed on emergence and transfer of the cultural aspects in construction project context. Contractor held a strong basic assumption that *"project culture was emerged and transferred with time, with continuous interactions and socialisations among team members"*. For example, the contractor had past experience with the consultant of project XYZ in a different project. Thus, contractor had appointed the same team of contractor's personnel for project XYZ as a strategic decision. Moreover, two senior members of the contractor's organisation (project coordinator and the construction manager) were appointed for this project despite the lesser contract sum of project XYZ (Sri Lankan Rupees 1.317 Billion) compared to the previous project (Sri Lankan Rupees 4 Billion) including an opportunity cost. Despite the opportunity cost, contractor had believed that it would be much easier to work and provide a better service and output to the client with a known team of consultants, where the cultural behaviours were properly internalized. Further, site engineer of the contractor mentioned that they had a better knowledge on working procedures of consultant's staff than the majority of the site staff of consultant who worked on contract basis. For example, in some situations, contractor was explaining the consultant's variation procedures to contract-basis site staff of consultant. Thus, this emphasis on previous experience with team members was in line with the explanations that culture would not develop and embed until the members start surviving by overcoming different crisis and critical situations (Schein, 1983) to internalise (Ashforth and Mael, 1989) properly.

Although contractor held the assumption that *"internalized cultural knowledge was beneficial for project success"*, consultant seemed not holding the same assumption. Thus, consultant had ended up appointing completely a new team of direct consultants for project XYZ except few members (Project Quantity Surveyor) from the previous project. Consultant's view was that when the project objectives were defined well and when every member knew the role expected from each member, they were not required to consider previous knowledge on cultural behaviour of the team members. Further, client also held a similar assumption to the consultant. They trusted the consultant as the party bounded to provide them with the required consultancy service for them. This belief was in line with the argument by Meudell and Gadd (1994) that short life organisations develop a culture by focusing on a clearly defined mission. The Consultant Project Architect justified the above stating; *"Project being short term is not a problem for working comfortably. What is expected from each party is clearly defined in construction contract and consultancy agreement at the beginning of the project. We can simply operate successfully in such an environment."*

Although the consultant did not consciously had a belief on advantages of internalised cultural knowledge, during interviews, the members of the consultant's representatives mentioned how easy it was to work in an environment, when project culture had internalised to the team members over mere cultural identification. For example, consultant project quantity surveyor mentioned how the transferred cultural aspects due to working history with the contractor had been beneficial to the project working environment stating: *"They respond quickly compared to other contractors for quantity surveying aspects. In previous project, we had to push them for documentation, but now they submit everything correctly. Now they know what we require. If it is a variation, sample documents, shipping documents and approved drawings are submitted very quickly. Mistakes are really less. Also, they attend for any missing document urgently without any hesitation."*

All team members including; client, consultant and contractor believed that culture being emerged and transferred through the 'key people' in a project, who are at higher levels of the hierarchy with more authority. Contractor expected that project operations would have been easy if, at least the 'key people' from the previous project had involved with project XYZ. When consultant project architect was questioned on how the process of familiarising and introducing newcomers to the project team happened, she mentioned that such a special induction procedure was not adopted or required since the senior members within the project never changed, stating; *"The key people coming to the meeting did not change up to date from client, contactor or consultant. Junior Quantity Surveyor was changed, but Senior Project Quantity Surveyor remained same. Since senior position was not changed, no issue occurred. This was because, senior person knew what was happening in the project. A similar thing was experienced when Junior Structural Engineer was changed."*

This was an evidence that it was the senior members or the members with higher authorities who had decided upon the behavioural norms, values and basic assumptions in a cultural context and those are transferred to the members down the hierarchy. Similarly, as indicated by the site engineer, contractor had not introduced every member of the contractor's team to the client. Only the key members were meeting up with the client and they never tended to change those members. This revealed that cultural aspects of client could get transferred to the contractor's team through the key members of the contractor only. Thus, this finding further confirmed the finding of Marrewijk (2007) and Schein (1983) that members at higher authority levels contribute more for culture creation.

Following empirical evidence related to the existence of three perspectives in a public sector construction project were observed during the study.

Integration Perspective of Project Culture: The behavioural norms of each sub-group (contractor-consultant-client) noted by other sub-groups are presented in Table 1. According to Table 1, commonly shared or integrated behavioural norms by all three groups were not apparent. However, it was visible through interviews and progress review observations that every sub-group tried to defend themselves as a group, every group had matters, which they thought not suitable disclosing to other parties and used construction contract and consultancy agreement as the ultimate defending arms for oneself.

Differentiation Perspective of Project Culture: Highly differentiated behavioural norms, demonstrating clear professional sub-cultures for the client, contractor and consultant were popular among the project team members (see Table 1). Only three instances were identified within this case study having commonly agreed sub-cultural behaviours, as highlighted in italic letters in Table 1. These included; contractor believing written communication modes as essential, contractor agreeing on unrealistic targets for the project without proper justifications and client trying to control the project deviating from the contract. Thus, how each sub-cultural group identified the other sub-cultural group was relative to their own assumptions on the other party. In addition, many behavioural norms were interrelated. An example, highlighting both situations is given subsequently.

Consultant Project Architect mentioned that they have a clear division among members as consultant and contractor. This was because, consultant thought that contractor was always **looking for lapses from consultant to turn them into claims and earn.** Consultant was not happy with the behaviour of contractor writing letters to inform the lapses of the consultant to use them for future claims. This was highlighted by both the Project Manager and the Project Architect. As mentioned by the Consultant Project Architect; "All consultants work together as a single entity. Contractor is kept separate because, they always send letters for any small delay of consultant or client targeting a claim. Once they sent something like a warning letter over some instructions to be issued by us. We realised that they were targeting a claim and issued the relevant architectural and structural drawings very swiftly. We quickly detect such behaviours and act accordingly." This had made the consultant be cautious with their work all the time and had lack of trust among the two parties. This lack of trust among the contractor and consultant had been identified by the client as well. This behaviour between contractor and consultant had driven them towards **formal written communication modes being the most popular between the two parties.** Contractor believed that their contractual rights could be protected only by getting instructions in black and white. This was because, written instructions by means of letters, drawings, log notes and meeting minutes provided them with proof during any legal action. However, client and consultant had a very cordial relationship where, **client had always depended on and kept faith on consultant**. Informal communication modes such as telephone conversations were the most popular among client and the consultant.

Table 1: Behavioural Norms of Contractor, Consultant and Client

	Indicated by Client	**Indicated by Consultant**
Behavioural Norms of Contractor	*Contractor was too formal in behaviour requiring all instructions in writing* *Contractor was used to agree with impractical targets without justifications* Contractor tried to conform and not to innovate Continuous monitoring by client and consultant was essential to increase productivity of the contractor Contractor had no trust on consultant Contractor was too stubborn in behaviour Contractor lacked attention on health and safety at site	*Formal methods of communication were essential to Contractor* *Contractor promised for unrealistic targets deliberately to satisfy the client* Contractor tried to pass all responsibilities and blames to the consultant Contractor usually brought in excuses when any important goal was not achieved Contractor tried to deliver the quality as expected by the consultant Contractor targeted for additional claims in every situation
	Indicated by Client	**Indicated by Contractor**
Behavioural Norms of Consultant	Government consultants were more disciplined and took more responsibility Consultant tried to pass responsibility to contractor Consultant responded quickly to client Consultant always respected client Consultant had no trust on contractor	Consultant was careless and lacked integration in works by different professionals Decisions made by the consultant were impractical Consultant tried to win client by whatever the means Consultant was very slow in response to contractor
	Indicated by Consultant	**Indicated by Contractor**
Behavioural Norms of Client	*Client tried to control the project deviating from the contract* Client respected the consultant Convincing practical aspects of construction to the client was difficult Client expected consultant to take legal risks Client tried to achieve every scope possible within the contract in terms of variations Decisions made by public clients were uncertain mostly Client had faith on consultant since consultant had a tough control on project cost Client tried to motivate the contractor and consultant by continuous pressing Client did not intervene consultant's role and depended on consultant	*Client tried to control the project deviating from the contract* Client only looked for mistakes Client only pushed on the target and did not look on the real problems.

Fragmentation Perspective of Project Culture: Several fragmented behavioural norms were identified among the three sub-cultural groups. These were the behaviours working against each other creating tension among sub-cultural groups. For example**, client complained that contractor was too stubborn and inflexible in behaviour and required continuous monitoring by the consultant and contractor to increase their productivity**. Similarly, contractor complained that **client tried to control the project deviating from the contract**. Thus, this had created a great tension and disappointments between client and the consultant. This behaviour of client was further confirmed by the consultant as well by indicating that client tried to motivate the contractor by continuous pressuring. The statement by the Technical Officer (Maintenance) of client; "*Contractor had the problem of lack of labour force. When we stressed from here only they increased the labour force. However, we were unable to get the speed we anticipated*." justified that. Contractor was disappointed with this tight controls laid in by the client. For example; Construction manager mentioned that: "*Client tends to shout out;* '*we want you to get this done*', '*why don't you do it quickly*'. *Once during a meeting, I happened to remind the client that we are governed by the contract and not by client or consultant. All the parties should obey the contract and then things get controlled.*"

In addition, some fragmented behaviours were noted between the consultant and the contractor too. Contractor had understood the **consultant as careless and lacked in integration of works by different professionals** within the consultant's sub-cultural group. An evidence for this behaviour was when, Project Design Engineer had designed structural details for massive round shaped external piers given by the Project Architect, mistakenly assuming a square shape. Moreover, contractor had constructed to the wrong detail of the design engineer. Subsequently, consultant had an argument over the issue that the mistake could have been identified by any prudent contractor by comparing the architectural and structural details. In the same way, consultant always complained **contractor having an adverse behaviour of trying to pass all the responsibilities and blames to the consultant**. This demonstrated how the fragmented behavioural norms collided creating tension between parties.

Thus, construction project culture was more in line with differentiated and fragmented views, than with the integrated view described by Martin (2004). This was due to highly differentiated professional sub-cultures with number of differentiated behavioural norms. Awareness of such differences could have helped removal of the misunderstandings among the sub-cultural groups as indicated by Gajendran *et al*. (2012). Further, awareness of fragmented behavioural norms could have helped removal of formal irrationalities deterring the progress of the construction project. In overall, these case study findings were related to a construction project operated under the traditional procurement method with measure and pay contract. Thus, findings could differ in other procurement arrangements such as relational type of contracts. In addition, Schein (1984) indicated that behavioural norms of individuals or groups in a culture are visible, but often not decipherable. As identified from this case study, it was difficult to provide reasons for the behavioural norms of the three sub-cultural groups. However, more insight into these behavioural norms of the sub-cultural groups could be attained by learning into the other cultural manifestations such as values and basic assumptions of the team members as described by Martin (2004).

5. CONCLUSIONS

The aim of this study was to explore the nature of existence of project culture in a public sector building construction project through an exploratory case study and develop propositions for further study. Construction project culture emerged and transferred with time with continuous interactions and socialisations. Transfer of culture was effective with proper internalisation of culture, which materialised with previous working history of the team members. This was because, it allowed continuous interaction and socialisation for a longer period. In addition, construction projects being short life organisations, project culture emerged focusing on clearly defined project objectives. Further, project culture was emerged and transferred through team members at higher authority levels.

Behavioural norms of construction team members were identified by studying how each sub-cultural group viewed the behavioural norms of other sub-cultural groups. How each sub-cultural group had identified the behavioural norms of other sub-cultural groups drastically differed and mostly related to their own assumptions about the other party. With regard to the existence of construction project culture, shared or integrated behavioural norms were not much popular within the selected case. Differentiated behavioural norms were clearly visible forming contractor, consultant and client professional sub-cultures. Many behavioural norms were existing in an interrelated manner. Several fragmented behavioural norms were available creating tension among contractor and client and contractor and consultant.

However, merely studying the behavioural norms of the construction project team members did not provide more insight into the construction project culture. These reasons could be hiding deep behind the values and basic assumptions of the project culture. Thus, learning such manifestations could assist elaborating deep into the construction project cultural context, which requires further research in this context.

6. REFERENCES

Ankrah, N. A. and Langford, D. A., 2005. Architects and Contractors: A Comparative Study of Organizational Cultures. *Construction Management and Economics*, 23(5), 595-607.

Ankrah, N. A., Proverbs, D., Antwi, A. and Debrah, Y., 2005. Factors Influencing Organisational Culture: A Construction Project Perspective. In: Egbu, C., Tong, M., eds. *Proceedings of the PRoBE 2005 Conference*, Glasgow, 729-742.

Ashforth, B. E. and Mael, F.1989. Social Identity and the Organization. *Academy of Management Review*, 14, 20–39.

Bower, M., 1966. *The Will to Manage*. McGraw-Hill, New York.

Cicmil, S. and Gaggiotti, H., 2014. The 'Slippery' Concept of 'Culture' in Projects: Towards Alternative Theoretical Possibilities Embedded in Project Practice. *The Engineering Project Organization Journal*, 4(2-3), 134-146.

Fellows, R., Grisham, T. and Tijhuis, W., 2007. Enabling Project Team Culture. In: Sexton, M., Kähkönen, K., Lu, S., eds.*CIB Priority Theme - Revaluing Construction: A W065 'Organisation and Management of Construction' Perspective, CIB report: Publication 313*, Rotterdam May 2007, CIB General Secretariat, 27-44.

Gajendran, T., Brewer, G., Dainty, A. and Runeson, G., 2012. A Conceptual Approach to Studying the Organisational Culture of Construction Projects. *Australasian Journal of Construction Economics and Building*, 12 (2), 1-26.

Harris, L.C. and Ogbonna, E., 1998. A Three-Perspective Approach to Understanding Culture in Retail Organizations. *Personnel Review*, 27(2), 104 – 123.

Hofstede, G., 2001.*Culture's Consequences: Comparing Values, Behaviours, Institutions, and Organizations across Nations*. Sage Publications, London

Kappos, A. and Rivard, S., 2007. Review: Cultural Interpretations from Multiple Perspectives: A Three-Perspective Theory of Culture, Information Systems and the Development and Use Processes. *HEC Montréal*, 1-57.

Kumaraswamy, M., Rowlinson, S., Rahman, M. and Phua, F., 2002. Strategies for Triggering the Required 'Cultural Revolution' in the Construction Industry. In: Fellows, R. F., Seymour, D. E., eds.*Proceedings of CIB TG-23—Perspective on Culture in Construction*, *CIB Publication 275*, September 2002. The Netherlands: CIB General Secretariat, 268-285.

Marrewijk, A., 2007. Managing Project Culture: The Case of Environ Mega Project. *International Journal of Project Management*, 25, 290-299.

Martin, J., 2002. *Organisational Culture: Mapping the Terrain.*CA, Sage, Newbury Park

Martin, J., 2004. *Organisational Culture (Research Paper Series, Stanford, Research Paper No 1847)*. Stanford Graduate Business School, Stanford

Meudell, K. and Gadd, K., 1994. Culture and Climate in Short Life Organizations: Sunny Spells or Thunderstorms?.*International Journal of Contemporary Hospitality Management*, 6(5), 27-32.

Schein, E. H., 1983. The Role of the Founder in Creating the Organisational Culture. *Organisational Dynamics*, 12(1), 13-28.

Schein, E. H., 1984. Coming to a New Awareness of Organisational Culture. *Sloan Management Review*, 25(2), 3-16.

Schein, E. H., 1990. Organisational Culture. *American Psychologist*, 45 (2), 109-119.

Schein, E. H., 2004. *Organizational Culture and Leadership*. Jossey-Bass, California

Tijhuis, W., 2011. Developments in Construction Culture Research: Overview of Activities of CIB W112 'Culture in Construction'. *Journal of Quantity Surveying and Construction Business*, 1(2), 66-76.

Yin, R. K., 2009. *Case Study Research-Design and Methods.*4thed. Sage Publications, New York

Zuo, J., 2008. *Project Culture in the Australian Construction Industry: Lessons for China*. Thesis (PhD). University of South Australia, Adelaide.

Zuo, J. and Zillante, G., 2005. Project Culture within Construction Projects: A Literature Review. In: *Proceedings IGLC-13*, Sydney, Australia July 2005. 353-361.

OPPORTUNITIES AND CHALLENGES FACED BY THE SRI LANKAN CONSTRUCTION COMPANIES IN THE STOCK MARKET

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ABSTRACT

In recent years, the social and technological changes originating from globalization, information revolution and knowledge-based economy fundamentally modified the construction industry environment. Local contractors need to originate a strategy to upgrade not only its technological capacity, but also the financial capacity to compete successfully in this landscape. Access to capital is one of the key strategic asset which contributes to the success of construction firms. This research focuses on to determine suitability of financing through the Stock Market for construction companies.

Survey approach was used to collect data. Mainly questionnaire was designed to identify the opportunities and challenges in the Stock Market for a construction company. Semi structured interviews were conducted to identify the strategies to enhance opportunities and face challenges in Stock Market. Preliminary survey was carried to structure the questionnaire.

The data gathered related to the challenges were analysed using SPSS one sample t-test and IPA matrix. Simple graphical analysis methods and manual content analysis technique also were used to analyse data. A total number of 22 opportunities related to the Stock Market for a construction company were identified during the questionnaire survey and semi-structured interviews. Then identified the 17 challenges related to the Stock Market for a construction company. However, just only 4 number of challenges were identified as critical challenges. Mechanisms available to enhance opportunities and to face challenges in the Stock Market were investigated. Finally, identified that financing through Stock Market is a better opportunity for the construction companies in Sri Lanka.

Keywords: *Construction Companies; Opportunities and Challenges; Sri Lanka; Stock Market.*

1. INTRODUCTION

Donaldson (1961) and Myers and Majluf (1984) discovered that companies use internal financing of funds from their operations. When internal funds are not adequate, companies would use external financing. The Public offering is an important financing method. Normally, shareholders expect a return from new equity issues, and like that the public is interested in contributing for shares (Kiymaz, 2000; Aaij and Brounen 2002). In addition to that Redman, Tanner and Manakyan, (2002) mentioned that Managers tend to look at the tax advantages of debt and availability of cash flows in determining which financing methods to use, more than theoretical corporate finance factors.

The Capital Asset Pricing Model (CAPM) has possessed a central position in financial economics over the twenty years since its origins in the papers by Sharpe (1964) and Lintner (1965). Moreover Bokpin (2010) mentioned that well-developed Stock Markets accommodate information acquisition, liquidity and diversification resource mobilization for corporate finance, growth and investment. Further, they mentioned that an active and liquid Stock Market help firms to finance their operations through equity capital than debt in the relatively cheaper way. Similarly, Olaleye (2011) mentioned that investors could consider the content of listed property stock in their portfolios with the anticipation of a significant return enhancement with marginal risk reduction.

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The political position of a country highly effects on the development of the Stock Market. At the end of a a ruinous 30 years of civil war, Colombo Stock Exchange has initiated to peak and became one of the best performing Stock Markets in Asia (Hettiarachchi, 2009).

The Colombo Stock Exchange (CSE) has 294 companies deputizing 20 business sectors with a market capitalization of Rs. 2,701.6 Bn as at 31st January 2017. Public companies established under the Companies Act No.7 of 2007 or any other statutory corporation, established or incorporated under the laws of Sri Lanka or incorporated under the laws of any other state (subject to Exchange Control approval) are eligible to look for a listing on the Colombo Stock Exchange to obtain debt or equity. Companies asking to be entered into the official list of the Exchange and to protect a listing of their securities will be required to conform to the relevant provisions of the above act and the Securities and Exchange Commission (SEC) Act No.36 of 1987 and the Listing Rules of the Exchange.

Listed companies in different industries have different market structures, profitability and industry life cycle, therefore listed companies performance, share price gains and investment risk differ from industry to industry (Zhao, 2013). Construction firms and commercial bank are two developing sectors of the Polish economy and dominate the Stock Market. This implies that growing companies contribute to its development and dominate the Stock Market (Kominek, 2004).

Under the Colombo stock exchange there are two registered contracting companies. Access Engineering (PLC) was listed on the CSE on 27th March 2012. The shares were listed on the Diri Savi Board and it is classified under the Construction and Engineering Sector (Colombo Stock Exchange, 2016). MTD Walkers PLC had been established as a Public Limited Company (PLC) in 1981 and it was listed on the Main Board of the Colombo Stock Exchange in 1983 (MTD Walkers PLC, 2016). According to the Polish economy, there is more involvement of construction companies in the Stock Market. But still Sri Lankan construction companies not that much involve with the Stock Market.

Very few studies have been conducted internationally and locally regarding to the involvement of construction companies in the Stock Market. Moreover, in other countries' economies like the Polish economy, there are more construction companies in the Stock Market. But still, in Sri Lanka there is no that much involvement of construction companies in the Stock Market. It shows that there is a problem related to this area. Hence, this research focused to identify the opportunities and challenges faced by Sri Lankan Construction companies when involving with the Stock Market.

The aim of the research is to identify the opportunities and challenges faced by the Sri Lankan Construction companies in the Stock Market and give recommendations to overcome the challenges. It is also expected to identify the differenet types of financing methods available for construction companies and to determine the suitability of financing through the Stock Market for construction companies.

2. LITERATURE FINDINGS

Shares of public listed companies are traded on the Stock Market. Companies float shares to the general public in an initial public offering (IPO) to accumulate capital in the primary market (Economic Times, 2016). Stock Market plays a major role in accomplishing capital requirement of the companies. For the long term fund requirements, issuing shares to the public is one of the most cost effective ways. Many researchers find that investment which requires long term funding affect to the economic growth and development of the country. Normally Stock Market is a complex place while the principles of it are straightforward. The Stock Market is the one of the most important place that a company can raise funds for its various needs like for further growth and expansion.

The Colombo Stock Exchange (CSE) has started to peak and became one of the best performing and promising Stock Markets in Asia after the end of a civil war, which has lasted over three decades in Sri Lanka (Hettiarachchi, 2009).

Financing is one of the salient areas in a firm. To maximize company's value and minimize the cost of capital, a manager should establish an optimum capital structure (Bokpin, 2010). Therefore, firms should attempt to determine the optimum capital structure that maximizes the firm's value. But no strict theory has been developed yet to determine the exact optimum capital structure (Sangeetha and Sivathaasan, 2013). Normally, managers identify factors influencing capital structure decision to make an optimum mix of debt and equity to maximize firm’s value (Puwanenthiren, 2011).

Literature review identified that equity and debt financing as major financing methods for companies. Equity, preference shares, debentures and bank loans are financing methods available for companies under equity and debt financing. Equity and preference shares come under the equity capital and debentures and bank loans comes under the debt capital. The most optimum capital structure is the debt-equity mix which maximize the firms’ value, so firms’ should attempt to optimize their capital structure by a suitable mix of debt-equity capital.

According to the Lawal *et al*. (2014), debt to equity ratio and total debt are negatively related to firm performance. Furthermore, they recommended that when firms financing their business they should use more of equity than debt. When interest rates are low equity is more expensive than debt. Although, if earnings decline, equity does not need to be paid back like debt. Maintaining a low debt-to-equity ratio also puts a company in a better position to get a loan in the future when needed. Debt and equity finance have both advantages and disadvantages as well. Thus, it is better to have a structure comprising of both debt and equity financing for the given project.

There are 295 companies which represent 20 business sectors in the Colombo Stock Exchange (CSE) as at 31st January 2017 (Colombo Stock Exchange, 2017).

Under the construction and engineering sector below companies are listed on the Colombo stock exchange

- MTD Walkers PLC
- Access Engineering PLC
- Colombo Dockyard PLC
- Lankem Developments PLC

MTD Walkers PLC and Access Engineering PLC are the main contracting companies among those four companies which registered under the construction and engineering sector of the Colombo stock Exchange.

Opportunities in the Stock Market for a company:

- Can raise new money anytime from the public
- Encourages employee by rewarding
- Ability to attract better employees
- Enhance the public image of the company
- Provides transparency around the value of the business
- Help to build a global business
- Spread the risk of ownership
- Indirect advertising
- Reduction of the cost of other capital

Challenges in the Stock Market for a company:

- Listing on stock exchange is an expensive and time-consuming process
- Ownership of the company can go to outsider’s hand
- Loss of Management Control
- Enhanced Reporting Requirements
- Increased Regulatory Oversight
- Increased Liability
- Perceptions of short-termism
- Dealing with institutional investors
- The Stock Market does not understand entrepreneurs
- Market fluctuations
- Responsibilities to shareholders
- Demands on the management team

3. RESEARCH METHODOLOGY

The survey approach was most suitable to achieve the aim and objectives of this research. Through literature review chapter secondary data for the research were collected. Preliminary survey, questionnaire survey and semi-structured interview survey were used to collect primary data. According to the findings of the literature review and preliminary survey, a questionnaire was developed for the questionnaire survey. Mainly questionnaire was designed to identify the opportunities and challenges in the Stock Market for a construction company. Preliminary survey was conducted with selected three resource person to validate the literature findings, to refine the research process effectively and to design the questionnaire. To achieve the third objective of this research; "to investigate mechanisms available for construction companies to enhance opportunities and to face challenges in the Stock Market", semi structured interviews were conducted until the data saturation.

The collected data through the initial questions in the questionnaire survey were analysed using graphical presentation tools like bar charts and pie charts. One sample T-test of SPSS statistical software was used to analyse data regarding challenges collected through the Likert scale. One Sample T-test which compares the means of unrelated variables on the same continuous and assumed test value for mean were used to identify the most significant challenges out of the challenges mentioned in the questionnaire. After calculating the mean of each challenge, challenges were mapped into the IPA matrix using SPSS software. The modified IPA matrix was used to present the two dimensions of the challenges which are the level of challenge and level of ability to overcome the challenge. Collected data from semi-structured interviews related to the mechanisms available for construction companies to enhance opportunities and to face challenges in the Stock Market were analysed using content analysis technique manually.

4. RESEARCH FINDINGS

4.1. STATUS OF CONSTRUCTION COMPANIES IN SRI LANKAN STOCK MARKET

According to the literature review, in other countries' economies like the Polish economy, there are more construction companies in the Stock Market. But still, in Sri Lanka there is no that much involvement of construction companies in the Stock Market.

The analysis of the questionnaire survey portrayed a substantial need of involvement of construction companies in the Stock Market. On the other hand, respondents shown that there are ample of opportunities to go public. Having such friendly market, still the establishment of construction companies as Public Limited Liability Company has been significantly hindered. One of the main underlying reasons was figured to be the most of the construction companies are family owned and don't like to give ownership to outside. Due to the fact that majority of the large construction companies are financially stable, it makes less enthusiasm for Sri Lankan construction companies to enter into the Stock Market with more risk and commitment.

On the other hand, the respondents of semi structured interviews mentioned that the current market can be dramatically varied in coming years, if construction companies open into international construction market. Accordingly, construction companies may need more capital, there is a high possibility that they would think about the Stock Market. Hence, this phenomenon portrays a need of identification of opportunities and challenges related to the Sri Lankan Stock Market for Sri Lankan construction companies. The results were figured to be the fact that construction companies would not be capable of seeing the bigger picture of how other countries' construction industry executes and it has to be upgraded with the awareness. After calculating the mean of each challenge, challenges were mapped into the IPA matrix using SPSS software. The modified IPA matrix was used to present the two dimensions of the challenges which are the level of challenge and level of ability to overcome the challenge. Collected data from semi-structured interviews related to the mechanisms available for construction companies to enhance opportunities and to face challenges in the Stock Market were analysed using content analysis technique manually.

4.2. *IMPACT OF INVOLVEMENT IN THE STOCK MARKET FOR THE CONSTRUCTION INDUSTRY*

The outcomes of the survey analysis revealed a significant impact by the involvement of construction companies in the Stock Market for Country Development. However, the survey revealed another fact that Sri Lankan construction companies are less focused on going public.

The outcomes of the study suggest that the Stock Market growth and economic growth have a long-run relationship. It reveals that the Stock Market liquidity do help to improve the future economy. Nowbutsing and Odit (2011) also found that Stock Market development is an important ingredient for growth in Mauritius since the Stock Market gives a general idea of an economy's health. More precisely, the causality runs from Stock Market proxies to economic growth shows a significant relation between market capitalization, total trade value and turnover ratio on the Gross Domestic Product (GDP) and FDI.

Stock Market performance and economic growth are just like a two sides of a coin. As the Stock Market increases economy is also fast in growth in the other hand downfall in make in market performance means slowdown of economic growth. Both are related to each other so have to create new ways to maintain growth of the market, saving and more investment. There is a need for economic growth in Sri Lanka, that’s why the emphasis should be more on the functioning of the Stock Market.

Normally, market capitalization affects positively to the GDP (Badr, 2015). The outcomes of the survey revealed that, Sri Lankan government must understand that it is time to find financial policies, to encourage companies and develop a financial Stock Market culture, and enhance to push companies to initiate IPOs instead of bank loans when money is needed to increase their investment.

4.3. *OPPORTUNITIES IN THE STOCK MARKET FOR A CONSTRUCTION COMPANY*

A total number of 10 opportunities were identified in the literature review as opportunities for a Public Limited Liability Company. In the preliminary survey, there were not added opportunities related to the Stock Market for a construction company. During the questionnaire survey new four numbers of opportunities related to the Stock Market for a construction company were identified. In addition to that, total number of 09 new opportunities have been identified during the Semi Structured Interviews. Accordingly, the total number of 22 opportunities related to the Stock Market for a construction company were identified during the questionnaire survey and semi-structured interviews.

Those 22 opportunities related to the Stock Market for a construction company are given below:

- Ability of gathering new capital at anytime
- Ability to create larger investor base
- Encourages employees by rewarding
- Ability to Attract Better Employees
- Enhance the public image of the company
- Provides transparency around the value of the business
- Help to build a global business
- Spread the risk of ownership
- Indirect advertising
- Reduction of the Cost of Other Capital
- Ability to attract foreign investors
- Increase the confidence on company financial position
- Improve the credibility on company financial statement
- Ability to gather government tax incentives
- Ability to acquire other companies and ability to grow
- There is a limitation that bank can issue loans, because of that it is better to go to the Stock Market when need of capital in high level
- Can accurately know about value of company by share price
- Strength cooperates governance
- Preference to get a loan
- Ability raises capital through right issue and debenture than a private company
- Exit mechanism to exit from the company when major shareholders want to exit from the company
- Accurate audited financial information help to prevent internal corruptions

4.4. *STRATEGIES THAT CAN BE TAKEN TO ENHANCE OPPORTUNITIES IN THE STOCK MARKET*

Suggestions for enhancing opportunities in the Stock Market were collected from semi-structured interviews with contractors and experts in the Stock Market. Interviewees were questioned for each of the opportunities regarding actions that can be taken to enhance opportunities. The sense of these experts has provided reliable and practicable strategies to enhance opportunities. According to the findings of the semi -structured interviews, below shows the actions that can be taken to enhance opportunities.

Respondents mentioned that, awareness program which emphasize benefits, will help to attract construction companies into the Stock Market. Moreover, respondents mentioned that, the government can give tax relief to construction companies, who are willing to list on the Stock Market. Other than that respondents mentioned that, the government can offer other financial incentives other than tax incentives.

According to the respondents they mentioned that, increased institutional and foreign client participation in the Stock Market will increase the visibility of the companies which are listed in the stock exchange. This will induce majority of the local large companies to list on the market. Moreover respondents mentioned that, there must be a need to collect capital from the Stock Market and without high need of capital companies do not need to list on the Stock Exchange. In addition to that increasing visibility of the Stock Market can cause to attract construction companies.

Furthermore respondents mentioned that, improving the market capitalization will help to enhance opportunities in the Stock Market. Hence, it is important that the government plays a key role in this regard by listing at least minority stakes of the non-strategic SOE’s (State Owned Enterprises) to increase liquidity and the market capitalization. Unless the government stronghold of the economy is reduced, the market participation rate of the private companies cannot be improved.

Moreover respondents mentioned that, government can release regulations that need to list on the Stock Market and after that they can control. In addition to that companies may not have trust about the Stock Market. Because of that Stock Market must create trust about the Stock Market and Stock Market must be an efficient market than manipulated market.

In addition to all those actions respondents mentioned that, the government can get action to enhance business opportunities related to the construction industry and open the Sri Lankan construction industry into international market. These actions may help to expand the construction companies and their need of Capital will increase with it.

Other than that, the government side companies also can get action to get the maximum out of the Stock Market. Respondents mentioned that, adhering to the listing procedures coupled with strict financial reporting procedures and capital adequacy will enhance the listing opportunities in the Stock Market. Furthermore, respondents mentioned that, if a company need to list on the Stock Market they must have a plan to establish financial and non-financial capabilities by ensuring good employer base and by increasing financial capabilities. Moreover, they mentioned that, listed company can use Debenture issue, Right issue and Warrant issue to attract capital by using their reputation. In addition to that respondents mentioned that, CSE is only a facilitator and a company limited by guarantee. The SEC is the government body who controls capital market. Government and companies must get action to enhance the opportunities in the Stock Market.

4.5. *CHALLENGES IN THE STOCK MARKET FOR A CONSTRUCTION COMPANY*

The total number of 13 challenges were identified in the literature review as challenges related to the Stock Market for a construction company. In the preliminary survey, three more challenges were added by the experts making the total number of challenges to 16. With the use of one sample t-test of SPSS software, 9 numbers of challenges were identified as significant challenges and 3 number of challenges have significant ability to overcome the challenge. Then, the 16 challenges were mapped in an IPA matrix. The challenges placed in the quadrant of high level of challenge and less level of ability to overcome (Quadrant D) were identified as the most critical challenges as per the concept of an IPA matrix by Martilla and James (1977). Accordingly, only the total number of 4 challenges were identified as critical challenges.

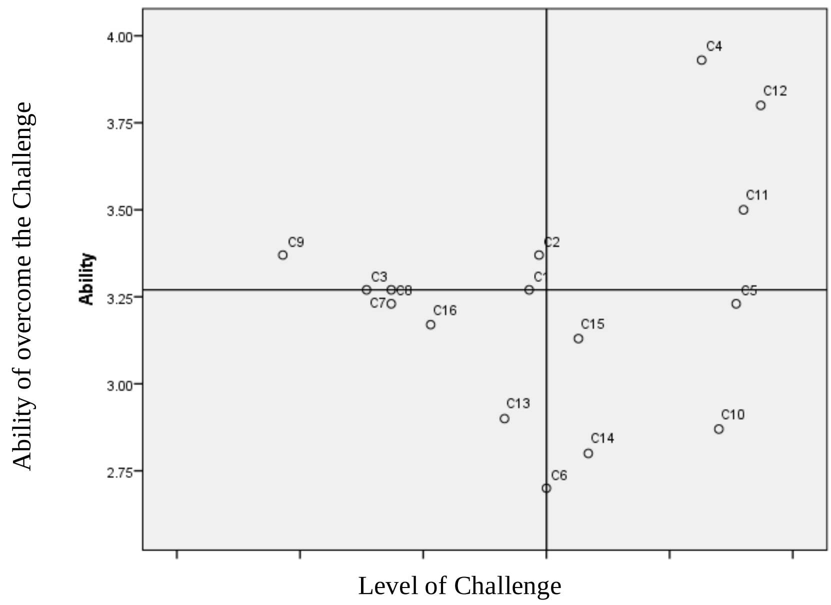

Figure 1: Modified IPA Matrix

Survey results identified the increased regulatory oversight (C5) as one of the most critical challenges. Similarly, the not having enough financial capabilities (C15) was also mapped in the quadrant that needs the high concentration. Further, market fluctuations (C10) were also classified under the above quadrant. Moreover, fluctuations in the construction industry (C14) were identified as a critical challenge even though it has been identified in the preliminary survey.

4.6. *ACTIONS THAT CAN BE TAKEN TO MINIMIZE CHALLENGES*

Identified mechanisms to overcome the challenges during the semi structured interviews can be summarized as given in Table 1.

Table 1: Strategies to Overcome Challenges

Challenges	**Strategies to Overcome Challenges**
Listing on stock exchange is an expensive and time-consuming process	Changing legislation Preparing accurate prospector in one time Outsource the listing process Just only consider about the essential requirements
Ownership of the company can go to outsider’s hand	Get consultant advice Issue limited Share Percentage
Loss of Management Control	Get consultant advices Enhanced Reporting Requirements Improve information system Just only consider about the essential requirements
Increased Regulatory Oversight	Ensure and maintain information timely and transparent manner
Increased Company Liability	Ensure good staff and good information system Establish profit maximizing activities Perceptions of short-termism Prevent from narrow profit maximizing targets
Bad relationship between financial stakeholders	Been more ethical and transparent Establish an investor relationship unit
Market fluctuations	Forecasting about the market Responsibilities to shareholders Correct disclosures on correct time
More responsibilities of management than private companies	Improve the performance of management Add more employees to the staff

Challenges	Strategies to Overcome Challenges
Fluctuations in construction industry	Diversification
Not having enough financial capabilities	Establish another board for Small and Medium scale companies
Not having trust about the construction industry in general public	Introduce awareness programs Maintaining better information system, talented staff, accurate financial statement and audit committee.

4.7. *Suitability of Financing through the Stock Market for a Construction Company*

When deciding the suitability of financing through the Stock Market have to consider about the advantages and disadvantages of equity and debt financing. During the literature survey financing methods and their advantages and disadvantages were identified. During the questionnaire survey respondent provided their ideas related to some advantages and disadvantages.

During the questionnaire survey, 72% of respondents said that, limited access to finance through generally and bank loans is a major barrier to innovation and industry development. In addition to that, 72% of respondents mentioned that, lack of affordable capital was a one of the major barriers to business growth.

Furthermore, during the questionnaire survey, 67% of respondent said that, companies listed on a stock exchange are much more popular and visible than privately held companies. 83% of respondents believed that, stock and share options programs can be used to attract top talented employees.

94% of respondents said that, motivation given by sharing ownership with the employees, employees tend to work for the profit maximization. In addition to that, when compared to other construction companies the performance of these companies has been highlighted than other companies' performance. After analysing all above findings, literature review findings and discussions under above sub-topics can suggest that, financing through the Stock Market is the best way to collect funds for a construction company.

5. Conclusions and Recommendations

After a ruinous 30 years of civil war, Sri Lanka is concentrating on long-term strategies to overcome challenges as it struggles to shift to an upper middle income country. In this background, the performance of the construction industry is serious, as the economy of the country mostly depends on it. Instead, the construction companies owe a duty to participate into the development of the country. In this phenomenon, involvement of construction companies in the Stock Market has been recognized as a huge reason for the development of the construction industry and the country. In this background, the research is aimed to discover strategic mechanisms to enhance opportunities and to face challenges in the Stock Market for the construction companies.

Literature review identified that equity and debt financing as major financing methods for construction companies. In addition to that equity, preference shares, debentures and bank loans are financing methods available for companies under equity and debt financing. Total number of 22 opportunities related to the Stock Market for a construction company were identified during the questionnaire survey and semi-structured interviews. Then identified the 16 challenges related to the Stock Market for a construction company. But, just only 4 number of challenges were identified as critical challenges. During the Semi Structured interviews the actions that can be taken to enhance the opportunities related to the Stock Market for a construction company were identified. In addition to that, the actions that can be taken to minimize the challenges related to Stock Market for a construction company were identified. After analysing all findings of the literature review, questionnaire survey and semi structured interviews can suggest that, financing through the Stock Market is the best way to collect funds for a construction company.

The construction companies have been grown effectively within last eras, not limiting to the Construction Industry. This expansion is now been unveiled the doors for construction companies which can have a huge contribution to the Construction industry and Sri Lankan the economy. Opportunities and challenges related to the Stock Market can create a significant effect to enter into the Stock Market. But in Sri Lanka less number of construction companies are listed on the Stock Market when compared to the other Countries. Therefore, this research clearly identified the opportunities and challenges related to the Stock Market and investigated the mechanism available to minimize challenges and enhance opportunities as recommendations to the construction companies.

6. REFERENCES

Aaij, S., and Brounen, D., 2002. High-tech IPOs: A tale of two continents. *Journal of Applied Corporate Finance*, 15(1), 87-94.

Badr, O.M., 2015. Stock Market Development and Economic Growth: Evidences from Egypt. *International Journal of Trade, Economics and Finance,* 6(2), 96-101.

Bokpin, G.A., 2010. Financial market development and corporate financing: Evidence from emerging market economies. *Journal of Economic Studies,* 37(1), 96-116.

Chinowsky, P.S., and Meredith, J. E., 2000. Strategic management in construction. *Journal of Construction Engineering and Management,* 126(1), 1-9.

Colombo Stock Exchange, 2016. *CSE - Colombo stock exchange*. [online] Available from: https://www.cse.lk/financial_reports.do [Accessed 22 June 2016]

Colombo Stock Exchange, 2017. *CSE - Colombo stock exchange*. [online] Available from: http://www.cse.lk/home/listByMarketCap [Accessed 22 February 2017]

Donaldson, G., 1961. *Corporate debt capacity: A research of corporate debt policy and determination of corporate debt capacity*. Boston, MA: Division of Research, Graduate School of Business, Harvard University.

Economic Times, 2016, June 10. *Definition of 'Stock Market' - The Economic Times*. [online] Available from http://economictimes.indiatimes.com/definition/stock-market [Accessed 10 June 2016]

Hettiarachchi, N.D., 2009. *Macroeconomic impact on Stock Market performance evidence from Colombo stock exchange* (Unpublished Master's thesis, University of Moratuwa, Moratuwa, Sri Lanka). [online] Available from http://dl.lib.mrt.ac.lk/handle/123/1456:// [Accessed 10 August 2016]

Kiymaz, H., 2000. The initial and aftermarket performance of IPOs in an emerging market: Evidence from Istanbul stock exchange. *Journal of Multinational Financial Management,* 10(2), 213-227.

Kominek, Z., 2004. Stock markets and industry growth: An Eastern European perspective. *Applied Economics,* 36(10), 1025-1030.

Lawal, B.A., Edwin, T.K., Monica, W.K., and Adisa, M.K., 2014. Effects of capital structure on firm’s performance: Empirical study of manufacturing companies in Nigeria. *Journal of Finance and Investment Analysis,* 3(4), 39-57.

Lintner, J., 1965. The valuation of risk assets and the selection of risky investments in stock portfolios and capital budgets. *The Review of Economics* and Statistics, 47(1), 13.

Martilla, J.A., and James, J.C., 1977. Importance-Performance Analysis. *Journal of Marketing,* 41(1), 77.

MTD Walkers PLC, 2016. *Corporate profile MTD Walkers PLC.* [online] Available from http://www.mtdwalkers.com/asian-property-development.html [Accessed 29 June 2016]

Myers, S.C., and Majluf, N.S., 1984. Corporate financing and investment decisions when firms have information that investors do not have. *Journal of Financial Economics,* 13(2), 187-221.

Nowbutsing, B.M., and Odit, M.P., 2011. Stock market development and economic growth: The case of Mauritius. *International Business and Economics Research Journal (IBER),* 8(2).

Olaleye, A., 2011. The effects of adding real estate into mixed-asset portfolios in South Africa. *Journal of Financial Management of Property and Construction,* 16(3), 272-282.

Puwanenthiren, P., 2011. Capital structure and financial performance: Evidence from selected business conies in Colombo Stock Exchange Sri Lanka. *Journal of Arts, Science and Commerce,* 2(2), 1-13.

Redman, A.L., Tanner, J.R., and Manakyan, H., 2002. Corporate real estate financing methods: A statistical study of corporations’ choices. *Journal of Corporate Real Estate,* 4(2), 169-186.

Sangeetha, M., and Sivathaasan, N., 2013, Factors determining capital structure: A case study of listed companies in Sri Lanka, *Research Journal of Finance and Accounting,* 4(6), 236-247.

Sharpe, W.F., 1964. Capital asset prices: A theory of market equilibrium under conditions of Risk. *The Journal of Finance,* 19(3), 425.

Vorasubin, P., and Chareonngam, C. 2007. Strategic assets driving financial capability of Thai construction firms. *Journal of Financial Management of Property and Construction,* 12(2), 87-94.

Zhao, Y., 2013. The relationship between share price gains, corporate performance and risk. *iBusiness*, 5(3), 110-112.

PREDICTING UNSAFE BEHAVIOUR OF CONSTRUCTION WORKERS

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ABSTRACT

The construction industry is known to be one of the most accident-prone of work sectors around the globe. Although the construction output is less in Sri Lanka, compared to developed countries in general, the magnitude of the accident rate in the construction industry is still significantly high. Most of the occupational accidents are due to the unsafe behaviour of the workers. Thus, studying the people-related factor in safety is an effective way to manage safety at work sites. This is a concept gaining more interest across industry sectors globally, and has the great advantage of needing the involvement of the individual employees. The paper therefore focused to investigate the factors influencing construction workers' unsafe behaviours and develop a model to predict unsafe behaviours based on those factors. The factors affecting construction workers' unsafe behaviour were identified through literature survey. Expert interviews were carried out to validate and generalize the factors found in literature, to the Sri Lankan context. Survey approach was used to collect data and the processed data were used to develop and train an Artificial Neural Network (ANN) model to predict unsafe behaviour of a construction worker. Then training and validation of the developed model under 7 design parameters was carried out using the data on influential factors of unsafe behaviour of 284 construction workers of C1 Building Construction sector. The data were applied to the backpropagation algorithm to attain the optimal ANN Architectures. The findings depict that the success of an ANN is very sensitive to parameters selected in the training process gaining good generalization capabilities in validation session. The model can be used to determine the unsafe behaviour level of construction workers and their safety training needs.

Keywords: *Artificial Neural Networks; Construction Industry; Unsafe Behaviour.*

1. INTRODUCTION

1.1. OCCUPATIONAL SAFETY IN CONSTRUCTION INDUSTRY

Occupational safety is among the most important performance indicators at worker level. The human, social and economic costs of occupational accidents, injuries and diseases and major industrial disasters have long been cause for concern at all levels from the individual workplace to the national and international (Alli, 2008). An International Labour Organization (ILO) report estimated that 2 million occupational fatalities occur across the world every year (ILO, 2003). The overall annual rate of occupational accidents, fatal and non-fatal, is estimated at 270 million (Hämäläinen *et al*., 2006). Measures and strategies designed to prevent, control, reduce or eliminate occupational hazards and risks have been developed and applied continuously over the years to keep pace with technological and economic changes. Yet, despite continuous if slow improvements, occupational accidents are still too frequent and their cost in terms of human suffering and economic burden continues to be significant (Alli, 2008). Especially the construction industry is struggling to improve the in this area (Gatti & Migliaccio, 2013). Compared with other industries; Construction is always risky because of outdoor operations, work-at heights, complicated on-site plants and equipment operation coupled with workers attitudes and behaviours towards safety (Choudhry and Fang, 2008). The nature of the construction industry's rapidly changing conditions, associated work hazards, and the characteristics of construction organizations further aggravate the situation (Wilson, 1989, Jannadi & Bu-Khamsin, 2002). Furthermore, Jannadi and Bu-Khamsin, (2002) asserted that the construction industry, being highly fragmented, marginalizes the efforts to

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maintain safety standards. At site levels, construction site activities are physically dispersed across various locations. Thus, supervising and monitoring safety issues in the workplace is much more challenging.

A large number of construction accidents are reported and thousands of workers are killed or injured on construction sites each year (Liu, 2013). According to Abudayyeh *et al*. (2006), the rates of fatal and nonfatal injuries and illnesses in the construction industry are relatively high and have not dropped significantly during the past 10 years, despite the adoption of safety procedures and programs such as those developed and required by the Occupational Safety and Health Administration (OSHA). According to Bureau of Labour Statistics estimates, there were 5,703 fatal and 3.9 million nonfatal workplace injuries in the United States in 2006 (Bureau of Labor Statistics, 2007). Further, in United Kingdom, 22% of employee fatalities and 10% of reported major injuries are in the construction industry despite only accounting for 5% of British employment (Health and Safety Executive [HSE], 2013). Sri Lanka is considered to be one of the most vulnerable countries, and is ranked at a low level for safety performance due to lack of improvement measures (De Silva & Wimalaratne, 2012). Further, compared to developed countries in general, the magnitude of the accident rate in the Sri Lankan construction industry is significantly high as reported in other countries such as USA (Chau *et al*., 2004), UK (Sacks *et al*., 2009), Hong Kong (Siu *et al*., 2003) and Singapore (Chau & Goh, 2004).

1.2. CAUSES OF CONSTRUCTION ACCIDENTS

Occupational accidents are defined as unplanned occurrences which result in injuries, fatalities, loss of production or damage to property and assets (Raouf, 2011). These accidents are caused. They are the result of unsafe behaviours (human error) and unsafe conditions, or a combination of both (Heinrich, 1931, Magyar, 2006, Al-Hemoud & Al-Asfoor, 2006). Unsafe behaviour is an element immediately prior to an accident event which is significant in initiating the event, while unsafe condition is unsatisfactory physical condition existing in the workplace environment immediately prior to an accident event which is significant in initiating the event (SafetyPortal, 2013).

Construction industry has managed safety mainly through focusing on improving the 'hard' issues such as managerial systems, policies and better safety technology, in other words, unsafe conditions. However, in recent times, many organizations have realized that their accident rates have 'leveled off'. This has ignited a search for improvements in other areas to reduce accident numbers; and has led to the research into behavioural safety issues of the workforce (Oswald *et al*., 2013). Thus, more recently researchers are debating that a majority of workplace accidents and injuries are attributed to the unsafe behaviours of employees rather than unsafe working conditions (Mullen, 2004). In a study examining contributory factors associated with 100 construction accidents (Haslam *et al*., 2005), 70% of accidents were estimated to have involved failure associated with human error (e.g., behaviour and capability). These failures included workers’ disregard for safety over other project priorities; inadequate hazard awareness and appraisal; and workers’ propensity toward least efforts to accomplish defined project goals.

Research has analysed unsafe behaviours in detail during the past. Accident causation was pioneered by Heinrich (1931) with his development of the domino theory. The domino theory asserts that 88% of all accidents are caused by unsafe acts of people, 10% by unsafe actions, and 2% by acts of God. There have been further considerable efforts towards investigating how accidents occur. Another accident ratio that is often referred to is the 80:20 ratio (80% unsafe behaviours, 20% unsafe conditions) (Al-Hemoud & Al-Asfoor, 2006); however if human factor aspects such as equipment/process design and work procedures to have an influence on the unsafe conditions, then the accident ratio would be changed to 96:4 (i.e., 80% of the 20% of the unsafe conditions is added to the original 80% of the unsafe behaviours and resulting in 80%+ 16%= 96%). This ratio considers that the human unsafe behaviour element is even more contributing to accidents.

2. UNSAFE BEHAVIOUR OF CONSTRUCTION WORKERS

Aunger and Curtis (2008) defined behaviour as self-propelled movement producing a functional interaction between a being and its environment. Another study conducted by Furr (2009) classified behaviour in to two categories as ‘contextual’ and ‘general’. The researcher defined globally retrospective behaviour as general and contextually retrospective behaviour as contextual. The research focuses on behaviour intended to represent how a person acts rather than how a person thinks, feels or otherwise responds. Further, the research been limited to a particular context and area of performance (construction an occupational safety respectively) the contextual behaviour was taken into consideration.

There is no general agreement on definition of an unsafe behaviour. However, it has been defined in similar focus on unaccepted practices which have the potential for producing future accidents and injuries. Further, an unsafe act is defined as a behaviour that is committed without considering safety rules, regulation, standards and specified criteria in system, which can affect the system safety level (Fuller, 2005). Number of acts of unsafe behaviour has been identified by many researchers such as Petersen (1984), Anton (1989), Stranks (1994), Simachokdee (1994), Michuad (1995), Abdelhamid and Everett (2000), and Holt (2001). These researchers identified various acts of unsafe behaviour those could lead to serious accidents or fatality, under interchangeably used terms and phrases. By reviewing that literature, the researcher was able to isolate fifteen distinctive unsafe acts of construction workers as listed below;

- Working without authority on the job
- Annoyance and horseplay in the workplace
- Smoking, creating naked flame or sparks in areas where flammable materials are stored
- Leaving nails or other sharp objects protruding from surfaces
- Throwing or dropping objects from high levels
- Working under the effects of alcohol
- Working with lack of concentration
- Working in poor physical conditions
- Working at improper speeds
- Improper posture for tasks
- Incorrect use of tools and equipment
- Using defective equipment and tools
- Ignoring to wear PPE
- Removing safety guards from the workplace or equipment
- Servicing equipment which is in operation

3. FACTORS INFLUENCING UNSAFE BEHAVIOUR OF CONSTRUCTION WORKERS

The literature review included studies that investigated unsafe behaviours and accidents in the construction industry. Empirical Studies with a substantive focus on identifying factors that influence the unsafe behaviours and accidents, studies in which the participants were construction employees and unsafe behaviours and accidents were work-related were reviewed. Literature provided a number of factors that have influence on unsafe behaviour of construction workers. When studying these factors closely they can be categorized in to three main constitutes as Person (Individual Dynamics), Process (Work Environment) and Place (Organisational Safety Culture) as shown in Table 1.

Table 1: Factors in Influencing on Unsafe Behaviour of Construction Workers

Factor	Reference
Person (Individual Dynamics)	
Age	Hinze, 1997; Sawacha *et al*, 1999; Carpenter *et al*., 2002; Parker *et al*., 2007; Seixas *et al*., 2008; Choudhry *et al*, 2009
Educational Level	Hinze, 1997; Carpenter *et al*., 2002; Parker *et al*., 2007; Seixas *et al*., 2008; Masood & Choudhry, 2012
Experience	Siu *et al*, 2003; Choudhry & Fang, 2008; Masood & Choudhry, 2012
Gender	Hinze, 1997; Carpenter *et al*., 2002; Parker *et al*., 2007; Seixas *et al*., 2008; Masood & Choudhry, 2012
Alcohol/drug abuse	Fang *et al*, 2006; Masood & Choudhry, 2012
Psychological distress	Abbe *et al*., 2011; Borys, 2012; Lai *et al*., 2011; López *et al*., 2008
Income	Choudhry & Fang, 2008; Fang *et al*., 2004; Hinze & Teizer, 2011; Suraji *et al*., 2001; Zheng *et al*., 2010
Attitudes towards OSH	Zohar, 1980; Cox, 1990; Cox & Cox, 1991; Dester & Blockley, 1995
Process (Work Environment)	
Hazardous Operation	Almen *et al*., 2012; Pungvongsanuraks *et al*., 2010; Vitharana *et al*., 2015; Abdul *et al*., 2003

Unsafe Conditions	Nouri *et al.*, 2008; Choudhry & Fang, 2008; Mitropoulos, 2005
Hazardous Equipment	Wachter & Yorio, 2014; Almen *et al.*, 2012; Abdul *et al.*, 2003
Place (Organisational Safety Culture)	
Management commitment to safety	Choudhry *et al.*, 2007; Pidgeon & O'Leary, 2000
Employee involvement	Kaskutas *et al.*, 2010; Meliá *et al.*, 2008
Proper safety procedures and rules	Aksorn & Hadikusumo, 2008; Choudhry & Fang, 2008
Efficient safety communication strategies	Borys, 2012; Meliá & Becerril, 2009

Artificial Neural networking was selected as the predictive modelling technique considering the context and scope of the study and data collected. Hecht-Nielson (as quoted by Caudill, 1987) defined the ANN as a computing system made up of a number of simple, highly interconnected processing elements, which process information by their dynamic state response to external inputs. Provided sample information, ANNs learn to generalize complex and nonlinear relationships and synthesize data for scenarios they have not experienced (Basheer, 1998).

In this research, the identified factors were validated to the local context through a pilot study. This is discussed under next section.

4. RESEARCH METHODS

In order to get the literature findings validated and further to identify specific variables that could be relevant under local practices, a pilot study was undertaken. Interviews were held with five managerial level experts having more than ten years of experience in the industry, of five reputed construction companies in Sri Lanka. 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. The pilot study was followed by the main survey to collect the numeric data necessary for model development and training via a questionnaire survey. A target sample of 400 C1 Building Construction workers was selected within Colombo Metropolis considering the scale of operations and the time constraint.284 complete questionnaires were returned, resulting a response rate of 71%.The achieved sample consisted of Masons (28%), Carpenters (13%), Electricians (11%), Plumbers (7%), Welders (9%), Riggers (14%), Concrete workers (9%), Bar-benders (7%) and Aluminium workers (2%). Cronbach's alpha was employed to evaluate items scored in multiple answer categories. It is the most common measure of internal consistency, commonly used when the study has multiple Likert questions in a survey/questionnaire that form a scale and scale reliability is to be assured (Bonett & Wright, 2014). The model developed was a neural network with 3 layers. Input layer included 14 neurons which were the influential factors and the output layer had one neuron representing the unsafe behaviour score (USBS). Hidden layer(s) of neurons were introduced to the network in the structure design (refer Figure 1). Neuroph Studio was the software used in model development and training.

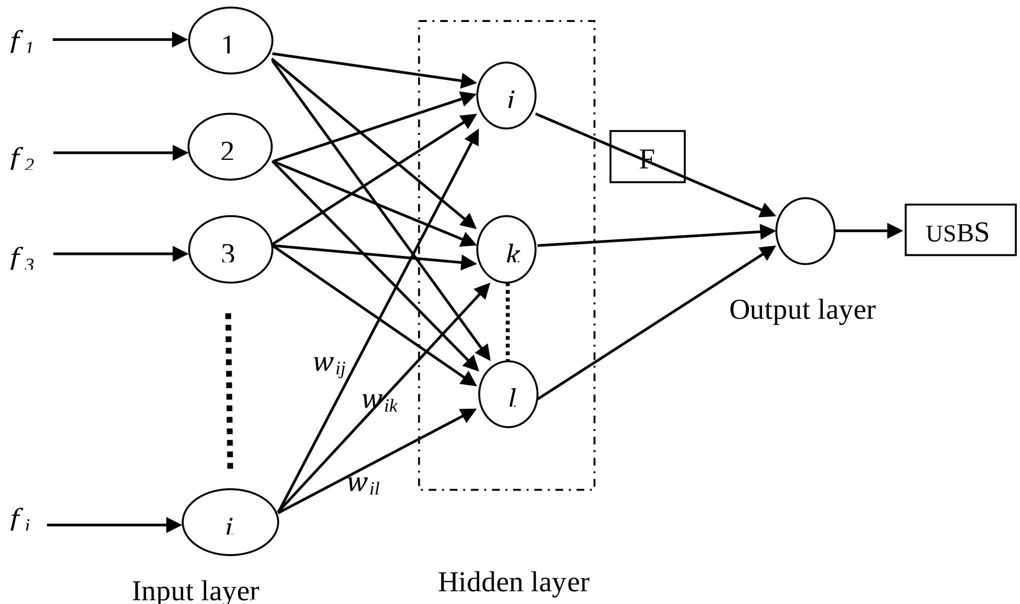

Figure 1: Network Structure Design

5. RESEARCH FINDINGS AND DISCUSSION

Pilot study findings confirmed the list of unsafe acts when experts agreed that it covers the unsafe behaviour of workers at construction sites profoundly. However, the influential factor list was moderated by the experts by removing 'gender' as a factor from the list. They pointed out that Sri Lankan construction industry is male dominated. All the other factors under the three constitute were approved by the experts. Based on the pilot study findings the questionnaire was developed and distributed. The completed questionnaires produced two datasets for data analysis as the data for calculation of the expected USBS and the data on influential factors. Dataset 1 included 15 items (variables) featuring unsafe acts committed by construction workers. Dataset 2 consisted of 14 items (variables) which were the influential factors of unsafe behaviour. The two datasets were analysed using Cronbach's Alpha for reliability of the scale score in SPSS. The reliability of the scale scores of Dataset 1 (Unsafe Acts) was 0.82 which is regarded as 'good reliability'; while the reliability of the scale scores of Dataset 2 (Influential Factors) was 0.795 which is interpreted as 'acceptable reliability'. Thus, the reliability analysis results proved that the two datasets were sufficient to proceed with the data analysis. Next subsection discusses calculation of the

5.1. CALCULATION OF EXPECTED USBS

The data collected through the questionnaire were used to develop the database using MS Excel. The data must be scaled into the range used by the input neurons in the neural network, which typically is the range of 0 to 1 (Mitchell, 1997). Thus, to normalize the data set, each data point was divided from the maximum attainable value of the variable which placed both the input dataset and the target output dataset within the range 0 to 1. Out of the 284 training cases available from data collection, 277 cases were included in to the training set. 7 cases were reserved for testing the network once it's trained. Based on the finding of ERI (2008), unsafe acts always have the potential to cause injury or death no matter the nature of the act or the excuse or justification used to commit them. Thus, each unsafe act found in literature is equally potential of causing an accident. Thus, the operationalisation of unsafe behaviour is the set of formative indicators (Unsafe Acts) supposing that the unsafe behaviour is the combined calculation of the different unsafe acts (Eq.1).

$$USBS = \sum_{i=1}^{n} (S_{ai}) \qquad (Eq. 1)$$

where:

ai is ith unsafe act, Sai is the Score of ith unsafe act, where ∀ Sai: 1≤Sai≤5 and n is the Number of unsafe acts.

On completion of the calculation of target output, a software package was to be decided upon which facilitates the design and training of the network in a comprehensive and user-friendly manner. Since the neural network model is hard to understand, the package to be selected must have the ability to simplify the NN model, reducing it to several parameters that users can alter. There are only few software products that offer full range of neural network customizable models, and they require expertise in understanding the neural network paradigm (Stojanovic, n.d). In open-source community, there are currently several stable neural network frameworks that offer to experts the tool for full customization of NN, models among those Neuroph is the most user-friendly and ample. Neuroph is lightweight Java neural network framework to develop neural network architectures. It contains well designed, open source Java library with small number of basic classes which correspond to basic NN concepts. It also has a good Graphical User Interface (GUI) neural network editor to quickly create Java neural network components. Thus, Neuroph Studio 2.8 was employed to design and train the Network. Next Section discusses the design and training of the ANN.

5.2. NETWORK STRUCTURE DESIGN

The multilayer feedforward neural networks are the most widely studied and used neural network model in practice (Vrajitoru, 2016). Feedforward neural networks are ideally suitable for modelling relationships between a set of predictor or input variables and one or more response or output variables. In other words, they are appropriate for any functional mapping problem where one wants to know how a number of input variables affect the output variable. Considering the research problem, it is clear that the feedforward neural network is the most suitable network type for the purpose. Three parameters determine the designing of the network:

number of neurons in the input, hidden and output layers. Generally, the input layer is considered a distributor of the signals from the external world. Hidden layer(s) are considered to be categorizers or feature detectors of such signals. The output layer is considered a collector of the features detected and producer of the response. However, the number of neurons in the input and output layers are pre-determined by the size of the input and output vectors respectively (Chew *et al*., 2004). For the created network, 14 input neurones and 1 output neurone were set as they represent the input and output data of the model. Additionally, bias nodes were added to increase the flexibility of the model to fit the data. Hidden layers were added in each training attempt and the number of nodes was changed until the optimum network obtained.

To train a neural network to perform a task, the weights of each unit must be adjusted in such a way that the error between the desired output and the actual output is reduced. This process requires that the neural network compute the error derivative of the weights. In other words, it must calculate how the error changes as each weight is increased or decreased slightly. The back-propagation algorithm is the most widely used method for determining error derivative of the weights (Zhang *et al*., 1998). Thus, a back-propagation algorithm with a 'log sigmoid' transfer functions in the hidden layer neurons will be used in the network training process.In this training, the total network error (E) is calculated as (Eq. 2);

$$E = \frac{\mathbf{1}}{\mathbf{2n}}\sum_{\boldsymbol{j=1}}^{\boldsymbol{n}}(\boldsymbol{T_j} - \boldsymbol{C_j})2 \qquad \textit{(Eq. 2)}$$

where:

n is the number of training samples, T_j is the target output of the jth training sample and $C_j$isthe corresponding computed output.

During the network training using Neuroph Studio, three learning parameters including max error, learning rate, and momentum were required to set. Learning rate was the constant in the algorithm of the ANN that affected the speed of training. Though the network would learn faster if the learning rate is high, if there is significant variability in the input, the network will not learn efficiently at a higher learning rate (Domingos, 2012). Thus, it was set at a low range to obtain smooth iterations in the training cycles.

A backpropagation network might settle to local minima by sliding down the error surface into a set of weights that does not solve the problem it is trained on. The Momentum allows the network to potentially skip through local minima (Rich *et al*, 2009). The training parameters were altered during the training until the optimum network is achieved. The stopping criterion (max error) for the optimum network was 0.01 while the learning rate was 0.2 and momentum was 0.7. It featured 20 neurons in the hidden layer. Shown in Figure 2 is the total network error graph of the optimum network. Figure 3 illustrates structure of the optimum network.

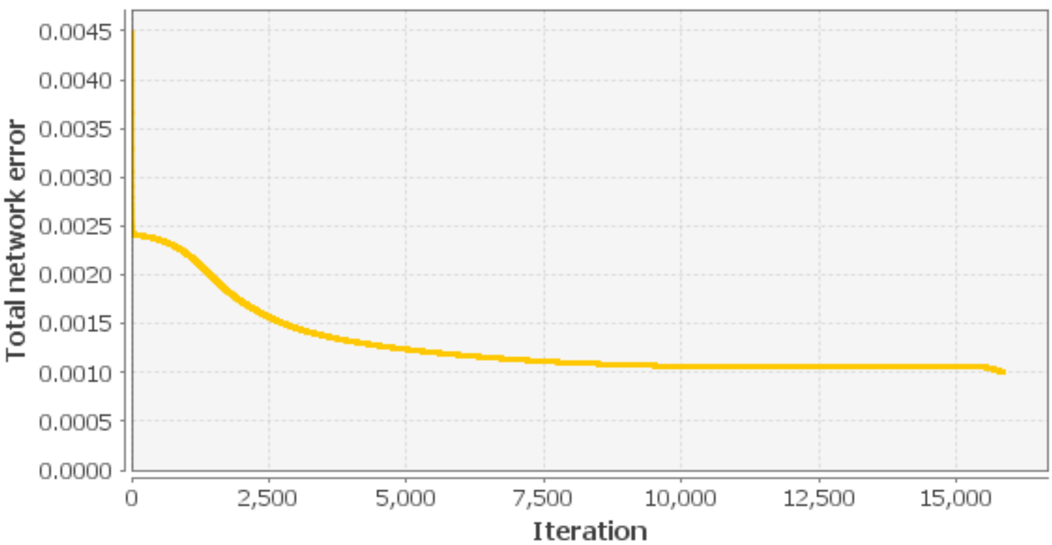

Figure 2: Total Network Error Graph of the Optimum Network

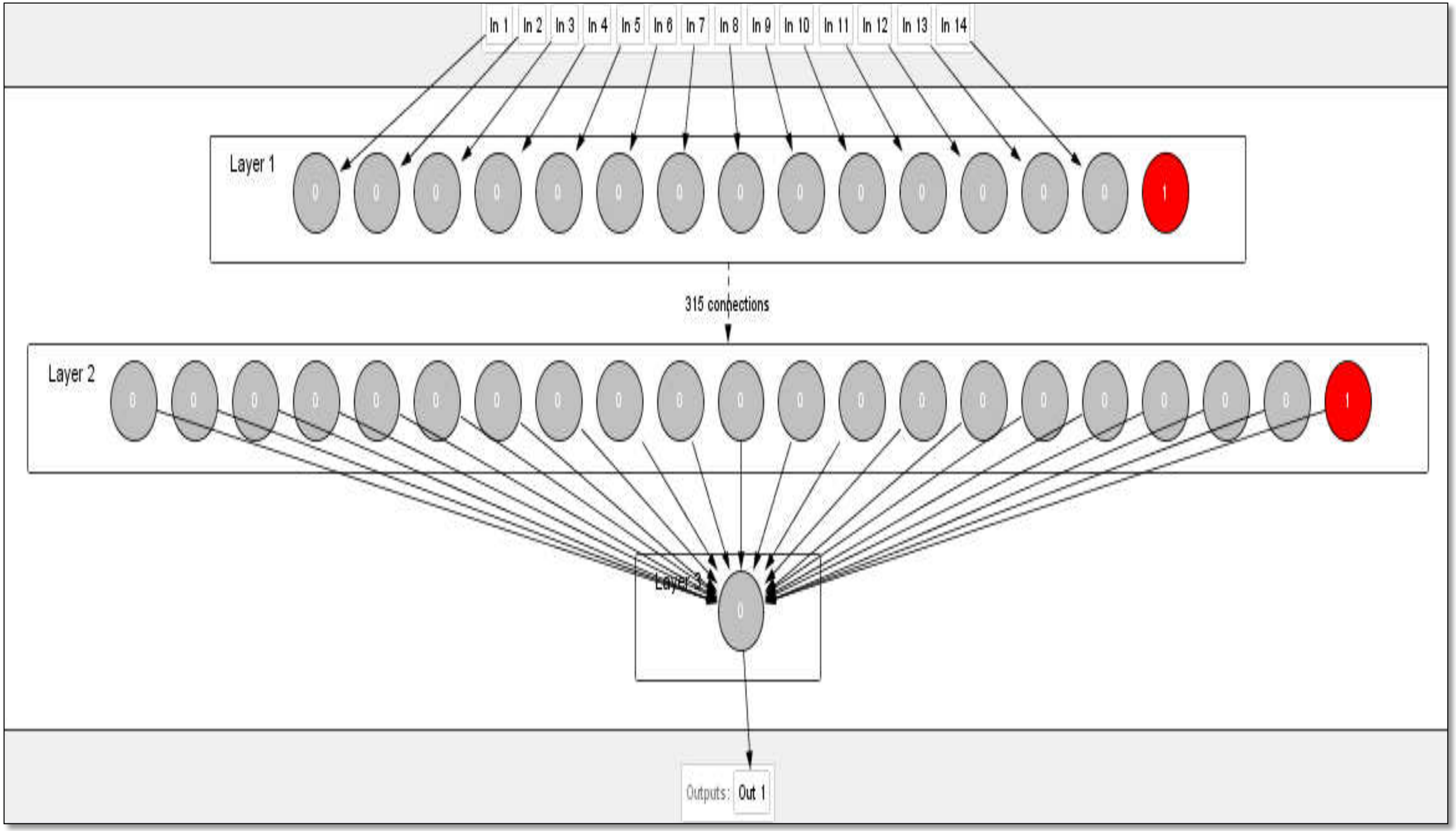

Figure 3: Structure of the Optimum Network

After training the network, 7 new data points were used to validate the network. Table 2 presents the validation results.

Table 2: Testing Results

Input	Network USBS	Expected USBS	Error
Case 1	0.286	0.293	0.007
Case 2	0.341	0.333	-0.008
Case 3	0.296	0.293	-0.003
Case 4	0.273	0.280	0.007
Case 5	0.288	0.293	0.005
Case 6	0.549	0.547	-0.002
Case 7	0.342	0.347	0.005

When considering the errors of the validation set, the error of each case was in the range of ± 0.01 which was the maximum error (1%), initially established for the predictive model. Hence, it can be concluded that ANN model has reached the expected performance level of the study.

6. CONCLUSIONS

The paper presents the findings on construction workers' unsafe behaviour and its influential factors. These factors were compiled from an in-depth literature review and further validated by a group of experts from the industry. In this paper, the identified factors are presented under three categories; namely, person, process and place. These acts of unsafe behaviour and influential factors were validated and moderated by the industry experts in the pilot study undertaken. While the experts confirmed the list of unsafe acts that characterise the unsafe behaviour, an influential factor, namely, 'gender' was omitted from the list considering the Sri Lankan context and significance to the subject matter, respectively. This moderated information was utilised in developing the questionnaire of the main survey, which targeted the workers in C1 Building contraction sites in Colombo metropolis, considering the scale of operation and the time constraint. Survey yielded a response rate of 71% and the generated data were utilised in developing a predictive model for construction workers' USBS. The internal consistency of the scales used in the questionnaire was tested using Cronbach's Alpha test and the model (neural network) was developed using Neuroph Studio software package. The optimum network was reached through trial and error method during training. The stopping criterion for the optimum network was 0.01 while the learning rate was 0.2 and momentum was 0.7. The network was then validated for generalisability using 7 new cases and the results confirmed that ANN model has reached the expected performance of the study. The developed model can be used in determining the safety training needs of workers who operate in the construction industry, based on the USBS.

7. REFERENCES

Abbe, O.O., Harvey, C.M., Ikuma, L.H. and Aghazadeh, F., 2011. Modeling the relationship between occupational stressors, psychosocial/physical symptoms and injuries in the construction industry. International Journal of Industrial Ergonomics, 41(2), 106-117.

Abdelhamid, T.S. and Everett, J.G., 2000. Identifying root causes of construction accidents. Journal of construction engineering and management, 126(1), 52-60.

Abudayyeh, O., Fredericks, T.K., Butt, S.E. and Shaar, A., 2006. An investigation of management's commitment to construction safety. International Journal of Project Management, 24(2), 167-174.

Aksorn, T. and Hadikusumo, B.H.W., 2008. Critical success factors influencing safety program performance in Thai construction projects. Safety Science, 46(4), 709-727.

Al-Hemoud, A.M. and Al-Asfoor, M.M., 2006. A behavior based safety approach at a Kuwait research institution. Journal of Safety Research, 37(2), 201-206.

Alli, B.O., 2008. Fundamental Principles of Occupational Health and Safety. 2nd ed. Geneva: International Labour Office

Almén, M.S, Bringeland, N., Fredriksson, R., and Schiöth, H.B., 2012. The Dispanins: A novel gene family of ancient origin that contains 14 human members [online] Available from: http://dx.doi.org/10.1371/journal.pone.0031961 [Accessed on 27 July 2015].

Anton, T.J., 1989. Occupational safety and health management, 2nd Ed. New York: McGraw-Hill.

Aunger, R. and Curtis, V., 2008. Kinds of behaviour. Biology and Philosophy, 23(3), 317-345.

Basheer, I. A., 1998. Neuromechanistic-based modelling and simulation of constitutive behaviour of fine-grained soils (Doctoral Dissertation). Kansas State University, Manhattan, Kansas.

Bonett, D.G. and Wright, T.A., 2014. Cronbach's alpha reliability: Interval estimation, hypothesis testing, and sample size planning, Journal of Organizational Behaviour, 36(1), 3-15. DOI: 10.1002/job.1960

Borys, D., 2012. The role of safe work method statements in the Australian construction industry. Safety Science, 50(2), 210–220.

Bureau of Labor Statistics, 2007. Workplace Injuries and Illnesses in 2006, USDL 07-1562. Washington, DC: U.S. Department of Labor.

Carpenter, W.S., Lee, B.C., Gunderson, P.D. and Stueland, D.T., 2002. Assessment of personal protective equipment use among Midwestern farmers. American Journal of Industrial Medicine, 42(3), 236-247.

Caudill, M., 1987. Neural Networks Primer, Part I, AI Expert, 2(12), 46-52.

Chau, K.H. and Goh, Y.M., 2004. Incident causation model for improving feedback of safety knowledge, Journal of Construction Engineering and Management, 130(4), 542-551.

Chau, N., Mur, J.M., Benamghar, L., Siegfried, C., Dangelzer, J.L., Français, M., Jacquin, R. and Sourdot, A., 2004. Relationships between certain individual characteristics and occupational injuries for various jobs in the construction industry: A case-control study. American Journal of Industrial Medicine, 45(1), 84-92.

Chew, M.Y.L., De Silva, E.N.D., and Tan, S.S., 2004. A neural network approach to assessing building façade maintainability in the tropics, Construction Management and Economics, 22(6), 581–594.

Choudhry, R.M. and Fang, D., 2008. Why operatives engage in unsafe work behaviour: Investigating factors on construction sites. Safety Science, 46(2), 566–584.

Choudhry, R.M., Fang, D. and Mohamed, S., 2007. The nature of safety culture: A survey of the state-of-the-art. Safety Science, 45(10), 993–1012.

Choudhry, R.M., Fang, D., Lingard, H., 2009. Measuring safety climate of a construction company. Journal of Construction Engineering and Management, 35(9), 890–899.

Cox, S., & Cox, T., 1991. The structure of employee attitudes to safety: A European example. Work & Stress, 5(2), 93–106.

Cox, S., 1990. Safety education and training. Basle, Switzerland: International Union of Pure and Applied Chemistry (IUPAC)

De Silva, N. and Wimalaratne, P.L.I., 2012. OSH management framework for workers at construction sites in Sri Lanka. Engineering, Construction and Architectural Management, 19(4), 369-392.

Dester, W.S., and *Blockley*, D.I., *1995*. Safety - behaviour and culture in construction, Engineering, Construction and Architectural Management, 2(1), 17-26.

Domingos, P., 2012. A few useful things to know about machine learning. Communications of the ACM, 55(10), 78-87.

ERI, 2008. There are no excuses for unsafe acts; Leaders' guide. Available from: https://www.erisafetyvideos.com/sites/default/files/2810lg.pdf. [Accessed on 4 May 2014]

Fang, D.P., Chen, Y., Louisa, W., 2006. Safety climate in construction industry: A case study in Hong Kong. Journal of Construction Engineering and Management, 132(6), 573–584.

Fang, D.P., Xie, F., Huang, X.Y., Li, H., 2004. Factor analysis-based studies on construction workplace safety management in China. International Journal of Project Management, 22(1), 43–49.

Fuller, C. W., 2005. An assessment of the relationship between behaviour and injury in the workplace: A case study in professional football. Safety Science, 43(4), 213–224.

Furr, R.M., 2009. Personality psychology as a truly behavioural science. European Journal of Personality, 23(5), 369–401.

Gatti, U.C. and Migliaccio, G.C., 2013. A study on the influence of construction workers' physiological status and jobsite environment on behaviour and performance. In 49th ASC Annual International Conference Proceedings, 10-13 April 2013, CA, USA.

Gunawardena, N.D. and Priyangika, L.M. 2005. Minimizing construction accidents through the integration of safety practices into ISO 9000 quality requirements, Built-Environment, 5(2), 28-33.

Hämäläinen, P., Takala, J., Saarela, K. L., 2006. Global estimates of occupational accidents, Safety Science, 44(2), 137–156.

Hamid, A.R.A., Yusuf, W.Z.W. and Singh, B., 2003. Hazards at construction sites. In Proceedings of the 5th Asia-Pacific Structural Engineering and Construction Conference, August 26-28, Johor Bahru, Malaysia, 95-104.

Haslam, R.A., Hide, S.A., Gibb, A.G.F, Gyi, D.E., Pavitt, T., Atkinson, S., Duff, A.R., 2005. Contributing factors in construction accidents. Applied Ergonomics, 36(4), 401-415.

Health and Safety Executive, 2013. Construction industry [online], Available from: http://www.hse.gov.uk/statistics/industry/construction [Accessed on 1 April 2014].

Heinrich, H., 1931. Industrial accident prevention. New York: McGraw-Hill.

Hinze, J., 1997. Construction Safety. New Jersey: Prentice-Hall Inc.

Hinze, J.W., and Teizer, J., 2011. Visibility-related fatalities related to construction equipment. Safety Science, 49(5), 709–718.

Holt, St. J.A., 2001. Principle of construction safety. London: Blackwell Science.

International Labour Organization, 2003. Safety in Numbers: Pointers for a Global Safety Culture at Work. Geneva: International Labour Office.

Jannadi, O.A. and Bu-Khamsin, M.S., 2002. Safety Factors considered by industrial contractors in Saudi Arabia. Building and Environment, 37(5), 539–547.

Kaskutas, V., Dale, A.M., Lipscomb, H., Gaal, J., Fuchs, M. and Evanoff, B.A., 2010. Fall prevention among apprentice carpenters. Scandinavian Journal of Work, Environment & Health, 36(3), 258–265.

Lai, D.N.C., Liu, M. and Ling, F.Y.Y., 2011. A comparative study on adopting human resource practices for safety management on construction projects in the United States and Singapore. International Journal of Project Management, 29(8). 1018–1032.

Liu, F., 2013. Construction accident overview [online], Available from: http://failures.wikispaces.com/Construction+Accident+Overview [Accessed on 4 April 2014].

López, M.A.C., Ritzel, D.O., Fontaneda, I., Alcantara, O.J.G., 2008. Construction industry accidents in Spain. Journal of Safety Research, 39(5), 497–507.

Magyar, S.V., 2006. Industrial accidents. Occupational Health & Safety. Available from: http://ohsonline.com/Articles/2006/07/Industrial-Accidents.aspx [Accessed on 5 April 2014].

Masood, R. and Choudhry, R.M., 2012. Investigation of demographic factors relationship with safety climate. In: 48th ASC Annual International Conference Proceedings, 11-14 April 2012, Birmingham, UK. 1-9

Meliá, .J.L, and Becerril, M., 2009. Health behaviour and safety in the construction sector. Psicothema. 21(3), 427–432.

Meliá, J.L., Mearns, K., Silva, S.A., Lima, M.L., 2008. Safety climate responses and the perceived risk of accidents in the construction industry. Safety Science, 46(6), 949–958.

Michuad, P.A., 1995. Accident prevention and OSHA compliance. Florida: CRC Press.

Mitchell, T., 1997. Machine Learning. New York: McGraw Hill.

Mitropoulos, P., Abdelhamid, T. and Howell, G., 2005. Systems model of construction accident causation. Journal of Construction Engineering and Management, 131(7), 816-825.

Mullen, J., 2004. Investigating factors that influence individual safety behaviour at work. Journal of Safety Research, 35(3), 275-285.

Nouri, J., Azadeh, A. and Fam, I.M., 2008. The evaluation of safety behaviors in a gas treatment company in Iran. Journal of Loss Prevention in the Process Industries, 21(3), 319-325.

Oswald, D., Sherratt, F., and Smith, S., 2013. Exploring factors affecting unsafe behaviours in construction In: Smith, S.D and Ahiaga-Dagbui, D.D (Eds) Proceedings of the 29th Annual ARCOM Conference, 2-4 September 2013, Reading, UK, Association of Researchers in Construction Management, 335-344.

Parker, D., Brosseau, L., Samant, Y., Pan, W., Xi, M. and Haugan, D., 2007. A comparison of the perceptions and beliefs of workers and owners with regard to workplace safety in small metal fabrication businesses. American Journal of Industrial Medicine. 50(12), 999-1009.

Petersen, D., 1984. Human-Error Reduction and Safety Management. New York: Aloray Inc.

Pidgeon, N. and O'Leary, M., 2000. Man-made disasters: why technology and organizations (sometimes) fail. Safety Science, 34(1), 15-30.

Pungvongsanuraks, P., Thitipoomdacha, C., Teyateeti, S. and Chinda, T., 2010. Investigation of safety divergences in Thai construction industry. In: Proceedings of the 2010 International Conference on Engineering, Project, and Production Management, 14-15 October, 2010, Pingtung, Taiwan, 151-158.

Raouf, A., 2011. Accident prevention [online], ILO Encyclopedia of Occupational Health and Safety. Available from http://www.ilo.org/oshenc/part-viii/accident-prevention/item/894-theory-of-accident-causes [Accessed on 1 April 2014].

Rich, E., Night, K., and Nair, S.B. , 2009. Artificial intelligence, 3rd ed. New Delhi: McGraw Hill

Sacks, R., Rozenfeld, O. and Rozenfeld, Y., 2009. Spatial and temporal exposure to safety hazards in construction. Journal of Construction Engineering and Management, 135(8), 726-736.

SafetyPortal, 2013. Unsafe acts and unsafe conditions [online]. Available from: http://www.safetyportal.info/tag/what-is-unsafe-act-unsafe-condition [Accessed on 18 September 2014].

Sawacha, E., Naoum, S. and Fong, D., 1999. Factors Affecting Safety Performance on Construction Sites. International Journal of Project Management, 17(5), 309-315.

Seixas, N.S. Blecker, H. Camp, J. and Neitzel, R. (2008). Occupational health and safety experience of day laborers in Seattle, WA. American Journal of Industrial Medicine, 51(6), 399–406.

Simachokdee, V., 1994. Safety engineering. Bangkok: Physics Center Press.

Siu, O.L., Phillips, D.R. and Leung, T. W., 2003. Safety climate and safety performance among construction workers in Hong Kong: The role of psychological strains as mediators. Accident Analysis and Prevention, 36(3), 359-366.

Stojanovic, J., n.d.. NeurophRM: Integration of the Neuroph framework into rapidminer [online]. Available from:http://neuroph.sourceforge.net/rapidminer/NeurophRapidMiner.html [Accessed on 10 May 2016].

Stranks, J., 1994. Human factors and safety. London: Pitman Publishing.

Suraji, A., Duff, A.R., and Peckitt, S.J., 2001. Development of causal model of construction accident causation. Journal of Construction Engineering and Management, 127(4), 337–344.

Vitharana, V. H. P., De Silva, G. H. M. J. S. and De Silva, S., 2015. Health hazards, risk and safety practices in construction sites – a review study. ENGINEER, XLVIII (3), 35-44.

Vrajitoru, D., 2016. Neural networks [online]. Available from: http://www.cs.iusb.edu/~danav/teach/c463/12_nn.html [Accessed on 27 August 2016].

Wachter, J. and Yorio, P., 2014. Investigating accident investigation characteristics & organizational safety performance. Journal of Safety, Health &Environmental Research, 10(2), 169-177.

Wilson, H.A., 1989. Organizational behaviour and safety management in the construction industry. Construction Management and Economics, 7(4), 303–319.

Zhang, G., Patuwo, B.E., and Hu, M.Y., 1998. Forecasting with artificial neural networks: The state of the art, International Journal of Forecasting, 14(1), 35–62.

Zheng, L., Xiang, H., Song, X., and Wang, Z., 2010. Nonfatal unintentional injuries and related factors among male construction workers in central China. American Journal of Industrial Medicine, 53(6), 588–595.

Zohar, D., 1980. Safety climate in industrial organizations: Theoretical and applied implications. Journal of Applied Psychology, 65(1), 92–102.

PROCUREMENT SYSTEM SELECTION MODEL FOR THE SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

Construction procurement system involves processes of acquiring services and products for the project activities starting from investigation up to the completion. With the development of new concepts and technologies, construction procurement arrangements have also advanced. Erroneous selection of a procurement system usually leads project to failure. Although, several procurement selection tools have been developed to minimize the adverse effect of overwhelmed wrong selections, those tools are not widely used in Sri Lanka (SL). Hence, it is vital to propose a new Procurement System Selection Model (PSSM) which can overcome barriers of existing PSSM.

A qualitative approach was used to identify prevailing practices and barriers to practice existing selection methods. Decision charts were developed by assigning average utility values for functional grouping, payment method and pricing mechanism.

Accordingly, the preliminary procurement system selection framework was arranged which includes seven steps namely; appoint an independent advisor, identification of project brief, identification and prioritizing factors affecting selection of procurement selection, choose functional grouping and payment modality, presentation of options found in step four in ascending order, selection of procurement strategy by the client and selection of parties involved in the project. Ultimately, proposed PSSM in this study merge the existing selection procedure in SL in a manner that leads selection into its best position. The study further recommends timely modernization of decision charts with Average Utility Value (AUV) and procurement systems, since suitability of each procurement system to selection criteria may change with development of construction industry.

Keywords: *Procurement System; Selection Criteria; Sri Lanka (SL).*

1. INTRODUCTION

Construction industry acquires a reputable designation in economic growth worldwide, which can set up the entire economic progression into the uppermost to lowermost in an uncertain manner. Hence, an advancement of the construction process comprises the potential for large cost saving, but the industry is still conservative and hesitates to accept strategies that are more efficient. With the availability of number of different procurement systems one of foremost daunting task which client and client advisors faces is selecting the most appropriate procurement system among the available procurement options. Even though procurement selection methods were developed, the practice of procurement selection is carried out in rather unstructured and ad hoc manner. Similarly, in Sri Lankan construction context there is no systematic realistic decision procedure used, to select the most appropriate procurement system for a particular project. Therefore, this research intends to address the problem of the reasons for the hesitance to use systematic selection method and thereinafter develop a comprehensive PSSM cooperative with Sri Lankan construction industry.

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2. PROCUREMENT SYSTEMS

The construction procurement; determined as the major element to achieve overall project strategic goals and the project success; structure that represents the distribution of responsibilities and authorities within participants involve in construction process (Ratnasabapathy and Rameezdeen, 2006). It addresses changes in economic, political, financial, technological and legal factors in efficient and effective manner which directly influence to the construction output, and loyal leadership; customer focus strategies; project team integration and focus to the quality of the industry; allure to use multifarious alternative construction procurement systems by the time (Rameezdeen and De Silva, 2002).

2.1. SUB-SYSTEMS OF PROCUREMENT ARRANGEMENT

Researches have divided procurement systems in several ways, as delivery system and contract system (New South Wales Construction Policy Steering Committee [NSW.CPSC], 2000) and further categorized as scope, organization, contract and award. Among those Kumaraswamy and Dissanayaka (1998) suggest more logical categorization of construction procurement system as shown Table 1.

Table 1: Sub Categories of Procurement Systems

Sub system	Description
Work packaging	The way slices work in to different packages vertically or horizontally, since the magnitude or the differentiations in geography, functional or disciplinary divisions (Kumaraswamy and Dissanayaka, 1997).
Functional grouping	The way of grouping functions of the project; design, construction, and management functions where responsibilities and authorities of each party is defined. E.g.: Separated, integrated, management oriented, PPP
Payment modalities	Valuation methods (fixed cost to cost reimbursement), currency, and the timing of the payments particular to the project
Form of contract	Conditions of contract varies as general conditions, special conditions which related to dispute resolution, special risks and standardize conditions
Selection methodology	Way of selecting consultant, contractor, Project Managers and other parties using negotiation, open tendering or envelop method

2.2. PROCUREMENT TRENDS IN SL

Due to the excessive demand for building and infrastructure projects the use of traditional procurement system can no longer meet clients' needs in an effective manner. In early 1900s, all the construction projects were procured under traditional systems and it continues until today with some modifications to improve cost, schedule and adversarial relationships through contractor centred approaches such as design and build in the private sector (Dorsey, 2004). As Dowd (1996) stated, construction management method began in 1960s and further developed in 1970s due to the economic recession. As well, consultative design and build also developed and project management emerged in 1980s' (Dorsey, 2004). Then in late 1990s and early 2000s management oriented approaches and collaborative working arrangements became more popular (McDermott and Khalfan, 2006). However, "Measure and Pay", under separated system domains the Sri Lankan construction industry from 1970s continuously, while usage of alternative procurement methods are neglected compared to other developing countries; So it means that, the Sri Lankan construction industry has not developed quite the same way as other developing countries (Ratnasabapathy and Rameezdeen, 2006).

Previous researches that have been carried out to identify different trends in construction procurement systems in SL by Rameezdeen and De Silva (2002), Ratnasabapathy and Rameezdeen (2006) and Jayasuriya (2010) presents the usage rates of procurement methods since 1970s. Table 2 presents trends in procurement systems used in SL from 1997 to 2009.

Table 2: Procurement Trends in SL

Procurement System	**% of use (average)**						
	1977-81	**1982-86**	**1987-91**	**1992-96**	**1997-00**	**2001-03**	**2004-09**
Separated System	77	68	71	61	77	78	80
– *Measure and pay*	55	50	58	50	64	72	69
– *Lump sum*	12	10	8	7	10	5	10
– *Prime Cost*	10	8	5	4	3	1	1
Integrated Systems	22	31	28	35	21	22	19
Management Systems	1	1	1	1	1	0	0
Collaborative Systems	0	0	0	3	1	0	1

The Table clearly highlight the dominance of separated system in SL, while “measure and pay” payment method stand with high popularity. However integrated system is identified as the second most popular procurement system but it decreased from 22 percent to 19 percent from 2004-2009. Jayasuriya (2010) stated that there is clear drop in usage of prime cost in large building projects with the rare existence of management oriented and collaborative systems in building sub sector. According to Shiyamini *et al.* (2005) the government as the regulatory body of SL has ignored practice of alternative procurement methods that emerged to enhance value for money and became the reason for the popularity of the measure and pay.

3. PROCUREMENT SYSTEM SELECTION

3.1. PROCUREMENT SELECTION METHODS

Ratnasabapathy and Rameezdeen (2006) stated that accurate choice of most appropriate procurement strategy drives to the realization of project specific goals and sidestep difficulties. Certainly, dissatisfaction about project success is the primary cause of selecting unearthly procurement strategy. The client or the representative, with their experience of past successful projects can choose the appropriate procurement method for the certain project (Mortledge, Smith, and Kashiwagi, 2006). Instead, inexperienced clients have to seek advices from procurement specialists (Love *et al.*, 1998). Hence, procurement system selection has become a complex and challenging task to client and the representative who seeks value for money. Since present expansion of different systems and clients with lack of knowledge about selection of most fitting system, has resulted in increased demand for systematic methods for selecting the most appropriate arrangement for the particular project. According to Love *et al.*, (2008) the approaches developed for procurement selection range from simple to highly complex. It is important that selection is undertaken sensibly, analytically and in well-organized manner by the clients’ principle advisor (Love, 1996).

3.2. DRAWBACKS OF EXISTING SELECTION METHODS

Guidance towards the selection of most appropriate procurement system must be accessible and incorporate a means of prioritizing client project criteria relating these to the suitability of the various procurement systems, to be valuable to users (Masterman, 2002). However, a number of drawbacks were identified with some or all of models, though all the models associated with various recognized approaches such as operational, statistical or electronic etc.; some of identified common drawbacks of existing selections are listed as follows;

- Only few factors are considered in almost all models for the main criteria of procurement selection and in some models, only some of clients’ requirements and project characteristics are considered (Ratnasabapathy and Rameezdeen, 2007).
- Limited number of variants of main procurement systems are included in existing models and ignored certain available procurement systems in the industry (Ratnasabapathy and Rameezdeen, 2007).
- Some of available methods are conditional which can only use by selected extent of clients, therefore not widely applicable
- Some of the models with the use of advance mathematical techniques, are not user friendly and bit time consuming

- Some of the models with the use of advance computer packages are not user friendly and highly cost to buy (Ratnasabapathy and Rameezdeen, 2007).
- Some of the models adopt to primitive approach, so limit the number of options to be considered
- The cost aspects of the selected procurement systems have not been incorporated (Ratnasabapathy and Rameezdeen, 2007)

4. CRITERIA CONSIDERED IN PROCUREMENT SYSTEM SELECTION

Manley (2008) stated employer as the ultimate governing decision maker even though the representatives or consultants can change the form of procurement system. Therefore, the selected procurement system bound to satisfy the client's needs and wants, effectively to give the value for client's money. In order to satisfy the client, all procurement system selection processes prioritize time, cost, and quality, which simply means that client expects high quality with lower cost and minimum time; yet balancing all basic needs is almost difficult, on the fact of one or both needs will suffer when trying to achieve one requirement (Bagnall, 1999). According to Ng *et al*., (2000), client's requirements or key drivers of the project, subjective to the background of the project take place, which means procurement selection criteria influenced by the factors drives externally to the project. Procurement method must address the technical features of the project with needs of client and contractor since each project has own unique characteristics. Accordingly, project characteristics such as type, size, complexity etc., should be considered in procurement selection. As a conclusion client's requirements and project characteristics which habitually influenced by external factors need to be considered when selecting appropriate procurement system to the specific project. Hence, procurement system selection criteria can be divide in to two major categorizes as illustrated Figure 1.

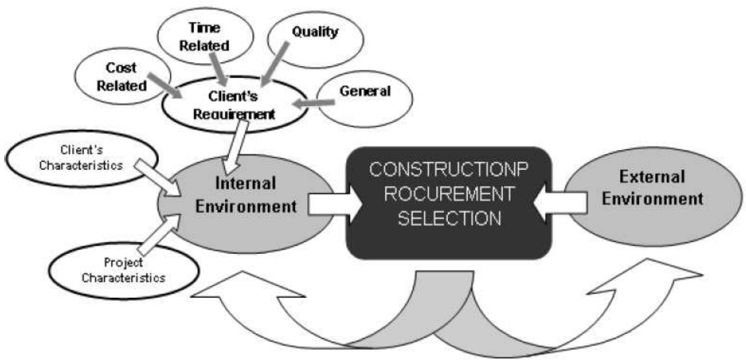

Figure 1: Categorization of Procurement System Selection Criteria

(Source: Rameezdeen and Jayasena, 2013)

4.1. CRITERIA CONSIDERED FUNCTIONAL ARRANGEMENT SELECTION

In Sri Lankan context, numerous researches were carried out to identify construction procurement selection. Gamage (2005) and Najeeb (2005) identified procurement selection criteria as clients' requirements, project characteristics and external environment factors; while Jayasuriya (2010) prioritized those factors according to SL's consideration. Further, Jayasena (2009) categorized criteria as private and public consideration. Following Table 3 describes the aforementioned identified factors affecting procurement selection.

Table 3: Factors Affecting Procurement Selection

Clients requirements	Upon basic three requirements (time, cost, and quality) risk management, price certainty, price competition, accountability, quality of work, familiarity, and flexibility for changes, responsibility and parties' involvement identified as clients' requirements.
Project characteristics	Factors like project cost and funding method, project complexity, project type, time constrains, degree of flexibility and disputes and arbitration are basically considered under project characteristics.

External environment factors	Projects cannot be isolated from the external environment and every project will receive impacts and information from the environment factors. Factors like market condition of the project, economic condition, technology, socio cultural suitability and regulatory environment identified as external environmental factors.

4.2. *CRITERIA CONSIDERED FOR PAYMENT MODALITY SELECTION*

The following Table 4 represents the criteria considered for payment modality selection.

Table 4: Criteria Considered for Payment Modality Selection

Time certainty	It is the ability to complete the project within the time agreed at the beginning of the time (Sherif and Kaka, 2003).
Price certainty	Establishing realistic cost estimate is vital in construction project, degree of faith of established price affected on selection of payment method for the particular project.
Forms of contracts	Available form of contracts provides guide to how and when contractor gets money entitle to him (Sherif and Kaka, 2003).
Contractor cash flow	Timing if cash inflow or outflow is vital and there can be time lags between intended for cash flow and actual timing of cash flow (Sherif and Kaka, 2003).
Speed (during Design and Construction)	Speed is very important factor of a construction project according to the client's need of the completion date.
Dispute likelihood	According to the nature of the project degree of arising dispute varies. However selected pricing mechanism and payment method need not help to arise new disputes.
Risk allocation	Various procurement paths including payment modality give different relationships and patterns of responsibility to the participants (Potts, 1988).
Project size	Construction projects are referred to different sizes. Larger size projects involve with more time and cost overruns due to complexity (Gamage, 2005).
Project complexity	Gidado and Millar (1992) stated that technical complexity, overlapping of design and construction phase, unpredictability decrease the performance of the works.
Procurement arrangement	Procurement arrangement is the way of allocating design, construction and management function responsibilities and authorities among parties to the project (Kumaraswamy and Dissanayaka, 1998).
Flexibility (accommodate the design changes)	Chan *et al*. (2001), flexibility is explained as up to what extent contractor is able to do changes for the design. Some procurement strategies are better than others in handling the introduction of changes later in the project (Kelly *et al.*, 2002).
Duration of tendering process	Clients' time requirement decides on availability of time for tendering process. As an example re-measurement is used where all the designs are not completed with limited time.
Tendering methods	Tendering methods can be classified as open, negotiation, selective etc. (Kumaraswamy and Dissanayaka, 1998). Duration, cost and agreement between parties vary according to the tendering method.
Value for money	Achieving value for money is the foremost expectation of introducing new theories to the construction industry (Miller *et al.*, 2009).
Project budget availability	Availability of the budget decides on the quality of the project and specifications (Ashworth, 2013). As well as limited budget drives to price competition.

4.3. *DOMINANT FACTORS CONSIDERED IN PROCUREMENT SYSTEM SELECTION IN SL*

According to Jayasuriya, (2010) "only limited number of procurement selection parameters have been considered for procurement selection" in SL; mainly nine factors were highlighted in that research as the critical factors that considered in SL construction context where other factors have not been considered to a great extent. Those factors are familiarity, price certainty, time availability and predictability, risk management, accountability, project cost and funding method, price competition, flexibility for changes, regulatory environment, and technology.

4.4. *PROCUREMENT SELECTION PROCESS IN SL*

The construction sector of SL has become one of major value addition to national GDP contributing 8.7% while recording an impressive growth of 14.4% in 2013 (Balachandran, 2014). By providing evidence to above, statement SL is having increase the number of industrial, commercial, official buildings and national scale mega projects. Anyhow, in most of cases clients are not satisfied with the manner in which their requirements are being met (Gunasiri, 1997). According to Ratnasabapathy and Rameezdeen (2007) construction procurement route is the key factor which leads project and employer to the expected success. So, it is essential to select procurement route carefully by considering internal and external factors to achieve economic benefits out of the project. In reality, do clients or their representatives actually use a structured model for procurement selection? According to Masterman (2002) the practice of procurement selection is rather unstructured and ad hoc. This observation is, of course, very true for a developing country like SL (Rameezdeen and De Silva, 2002).

5. RESEARCH METHODOLOGY

Qualitative survey approach was selected to observe Sri Lankan procurement experts opinions on reasons for the hesitance of procurement experts to adopt systematic procurement system selection method. Research technique for the study mainly consists of two processes as data collection and data analysis. Data collection for the study was conducted in two phases. First phase was to identify present procurement selection process and hesitance to adopt selection method in Sri Lanka was fulfilled through preliminary interviews. Three public sector procurement experts as well as three private sector procurement experts were selected and semi structured interviews were conducted. Procurement experts who attended for interviews by designation limited to the Quantity surveyors with more than 10 years' experience. Table 5 provides the respondents profile for the semi structured interviews carried out.

Table 5: Respondents' Profile for the Semi Structured Interviews

Interviewee	Carrier	Experience	Sector
Interviewee A	Senior Quantity Surveyor	14 years	Private
Interviewee B	Senior Quantity Surveyor	10 years	
Interviewee C	Chief Quantity Surveyor	18 years	
Interviewee D	Chief Quantity Surveyor	15 years	Public
Interviewee E	Chief Quantity Surveyor	20 years	
Interviewee F	Chief Quantity Surveyor	14 years	

Second phase to prepare Procurement Decision Chart (PDC) was accomplished through three rounds of questionnaire surveys to identify factors and attain utility values against procurement arrangements. Forty (40) professionals who involved with building construction procurement process were selected. The sample consist with Project managers, Construction managers and chief quantity surveyors who have more than five years' experience in private sector. Table 6 represents the demographic characteristics of survey sample. Snowball sampling method under non-probability sampling was used due to lack of personal contacts with procurement experts in the Sri Lankan construction industry.

Table 6: Demographic Characteristics of Survey Sample

Profession	Experience (X) in SL	Experience (X) out of SL	No. of recipients
Project Managers	X > 5 years	X > 15 years	2
	X > 5 years	X < 15 years	3
Construction Manager	X > 5 years	X > 15 years	2
	X > 10 years	X > 15 years	1
Chief Quantity Surveyor	X > 5 years	X > 5 years	7
	X > 10 years	X > 5 years	5
Project Quantity Surveyor	X > 5 years	X > 5 years	9
	X > 10 years	No X	11
		Total	**40**

Data produced from the preliminary interviews was the views and opinions of participants, which were text data but not numbers. Content analysis technique was used to analyse preliminary interviews and transcripts were produced in the way of conversation and analysed opinions of experts manually. Finally, the analysis was used to prepare preliminary procurement system selection framework.

Data produced from questionnaires was quantitative data at all three rounds. Hence, the analysis was done using Mean Weighted Rating (MW), Severity Index (SI), Coefficient of Variations (COV) and Concordance of Coefficient (W).

6. RESEARCH FINDINGS

6.1. *PROCUREMENT SYSTEM SELECTION MODEL*

Identify present procurement selection process and hesitance to adopt selection method in Sri Lanka

According to five out of six expert's experience, 80%-90% projects in SL are based on separated re-measurement method since industry is reluctant to adopt developed methods and government promotes traditional methods in order to protect transparency. Moreover, private sector experts highlighted that, past few years individual employers had selected design and build method with lump sum pricing as a trend without any advice from consultants and majority of those projects ultimately became failures. Therefore consultants also promote separated re-measurement method. Another argument was that clients' requirements are vague and client neither have knowledge nor familiar to interpret their requirements as appropriate to other procurement systems. Similarly, with the failures happened last few years by using other procurement methods, clients are anxious to occupy with other procurement methods. However, getting advice from a consultant was suggested by all the interviewees prior to using any kind procurement method. Present selection of procurement system happens generally based on personal criteria adopted by consultants based on their experience. The following steps are identified for the existing process;

- 1st step – meeting client and consultant, identify clients objectives
- 2nd step – selection of procurement system by the consultant

According to expertise opinion non-availability of understandable model, Existing models are not prepared for Sri Lankan context, Non availability or unawareness about standard documents for other procurement systems other than separated system or design and build systems, Existing models only consider about established method but not bespoke methods are most common reasons to not adopt to systematic procurement selection method. And also expertise expecting easiness of use, time saving, easily understandable process, transparency of system selection process from procurement system selection method when using it. With the opinions of expertise procurement system selection framework were produced. Ultimately PSSM illustrated in Figure 2 was produced using the framework.

In order to perform 4th step of the PSSM, the Procurement Decision Chart shown in Figure 3 was developed using Multi Attribute Utility Technique (MAUT), which is a methodology developed to help decision-makers assign utility values, taking into consideration the decision-makers' preference, to outcomes by evaluating these in terms of multiple attributes and combining these individual assignments to obtain overall utility measures (Meteo, 2012) as mentioned in following paragraph.

AUVs which represents relationship between identified criteria and various procurement methods, were obtained for functional groups, payment method and pricing mechanism as shown in Tables 7,8 and 9. AUV calculated using utility values which were assigned by the expertise in the questionnaire survey. Lower AUV represents lower suitability of particular procurement method referred to particular criteria while higher AUV represents higher suitability of particular procurement method referred to particular criteria. When selecting a procurement method in real life advisor can determine weightings from 1-10 against each criteria particular to specific project. After advisor assigned weightings against each criteria, weighting is multiplied by AUV under the each options. Then sum of results under every option is compared and ranked in descending order. Option, which gets first rank will be chosen as the most suitable option.

Table 7: AUVs for Procurement of Functional Groups

	Selection Criteria	Procurement Functional Grouping											W
		Separated		Integrated					Management Oriented				
		Seq.	Acc.	D&B	PD	TK	D&C	Nov	MC	CM	D&M	PM	
1	Financial risk	70.3	65.7	76.3	91.2	89.7	83.4	83.5	62.4	66.1	60.3	74.5	0.4623
2	Construction time	51.4	71.5	84.7	77.8	75.4	80.3	75.4	59.5	61.7	60.2	72.9	0.5087
3	The early start of project	49.4	56.7	89.4	98.2		80.5	73.9	67.4	66.0	71.4	77.4	0.4015
4	Price certainty	64.3	76.9	76.8	100.0	100.0	74.4	77.6	71.4	71.2	70.4	79.6	0.3276
5	Price competition	93.2	92.6	81.3	64.9	53.4	76.0	42.7	67.9	65.8	61.2	58.4	0.6461
6	Accountability	82.6	80.5	69.0	48.3	57.7	72.9	73.6	81.9	84.7	83.4	88.3	0.5100
7	Functionality	65.0	61.7	72.8	83.4	70.9	73.5	74.8	87.3	81.0	83.8	88.2	0.4289
8	Familiarity	96.8	96.8	82.8	70.1	45.6	44.8	61.0	38.9	46.2	40.5	56.7	0.7120
9	Client's flexibility	56.8	62.1	78.9			76.5	77.2	81.4	80.6	81.3	82.6	0.3791
10	Allocation of responsibilities												
	-Contractor only			100	100	100							1.0000
	-Consultant and Contractor	100	100				88.4	92.4					0.7516
	-Involvement of Construction Manager								100	100	100	100	1.0000
11	Project cost	63.6	66.6	84.2	85.3	79.4	70.1	73.1	67.9	69.4	68.7	69.3	0.3001
12	Degree of complexity	54.3	56.3	89.4	45.8	52.9	82.5	80.6	87.3	85.4	86.1	58.3	0.4386
13	Project type												
14	Time constraints	61.6	59.9	76.4	81.3	79.8	64.2	60.5	65.8	62.3	62.4	63.9	0.4592
15	Degree of flexibility	82.5	76.3	52.3	69.3	48.8	72.5	73.4	74.9	73.1	70.6	75.7	0.3847
16	Dispute and Arbitration	84.5	81.7	42.9	32.7	30.1	45.8	47.3	75.3	74.3	72.0	77.7	0.4945
17	Market condition for the project	78.6	83.7	81.2	60.2	72.9	64.9	65.8	56.7	59.0	62.1	65.9	0.3099
18	Technological feasibility	71.0	65.9	45.7	44.3	41.8	49.1	56.3	80.2	74.5	72.6	82.0	0.3618
19	Cultural differences	61.4	60.7	54.5	67.4	62.1	59.0	58.4	79.3	79.5	81.4	80.7	0.2019
20	Education of builders	66.9	69.4	85.8	86.2	88.1	85.4	82.3	71.6	72.3	75.2	74.1	0.4456
21	Regulatory feasibility	78.2	77.3	70.3	76.3	68.7	69.2	72.4	53.2	54.3	48.0	55.1	0.3534

Seq.-Sequential, Acc.-Accelerated, D&B-Design & Build, PD-Package Deal, TK-Turn Key, D&C-Develop & Construct, Nov-Novation, MC-Management Contracting, CM-Construction Management, D&M-Design & Manage, PM-Project Management

Table 8: AUVs for Procurement of Payment Method

	Selection Criteria	Procurement Payment Method						W
		With Advance Payment			Without Advance Payment			
		IP	MP	SP	IP	MP	SP	
1	Contractor cash flow	70.8	71.9	77.1	52.4	45.3	68.3	0.5608
2	Financial risk	82.0	69.1	62.7	69.3	63.2	60.4	0.4012
3	Tendering method							
4	Project duration	68.5	77.1	83.5	61.4	74.8	82.9	0.7725
5	Familiarity	87.0	85.6	54.2	81.9	73.9	45.1	0.7100
6	Project type							
7	Risk management	70.2	78.2	63.8	55.3	52.1	49.9	0.4148
8	Contract form							
9	Price certainty	60.9	56.7	73.6	75.9	61.0	60.8	0.4512
10	Speed (during D & C)	83.5	79.3	78.1	64.6	60.2	57.3	0.5385

IP-Interim Payment, MP-Milestone Payment, SP-Stage payment

Table 9: AUVs for Procurement of Pricing Mechanism

	Selection Criteria	Procurement Pricing Mechanism									W
		Price based		Cost based		Target price					
		R-M	LS	C + PF	C + FF	GMP	Alliance				
							Pure	Comp.	Hybrid	Prog.	
1	Familiarity	81.3	80.2	70.4	64.0	65.3	21.0	18.4	19.8	11.1	0.6791
2	Price certainty	71.6	76.9	61.2	66.6	73.1	77.4	79.1	76.0	81.3	0.3502
3	Risk management	56.7	77.8	59.9	69.5	62.4	80.3	82.1	79.6	80.2	0.5163
4	Flexibility for changes	85.5	66.0	80.8	81.6	63.5	54.8	54.1	51.0	52.3	0.5623
5	Project cost and funding method	72.4	78.7	63.5	65.8	77.6	74.1	80.3	78.1	61.0	0.4821
6	Project complexity	63.4	80.5	59.1	51.4	55.2	88.6	87.1	87.4	81.8	0.5900
7	Functional grouping	82.3	80.6	77.1	70.5	55.4	43.7	40.9	55.2	34.3	0.6607
8	Disputes likelihood	85.1	61.7	71.5	73.0	62.3	55.3	59.1	79.4	46.7	0.4011
9	Tendering methods										
10	Economic Condition	55.1	82.3	63.9	65.2	53.6	67.1	66.8	78.5	43.0	0.3727
11	Tendering time	61.9	86.8	54.2	55.9	64.2	74.5	52.0	76.9	75.0	0.4045
12	Client experience	60.8	80.9	77.3	65.4	60.9	52.0	55.2	67.7	45.3	0.5946
13	Value for money	50.4	77.4	32.4	38.3	79.8	81.0	54.6	65.1	82.5	0.4500

R-M-Re-Measurement, LS-Lump sum, C+PF-Cost plus percentage fee, C+FF-Cost plus fixed fee, GMP-Guaranteed maximum price, Comp-Competitive, Prog.- Programme

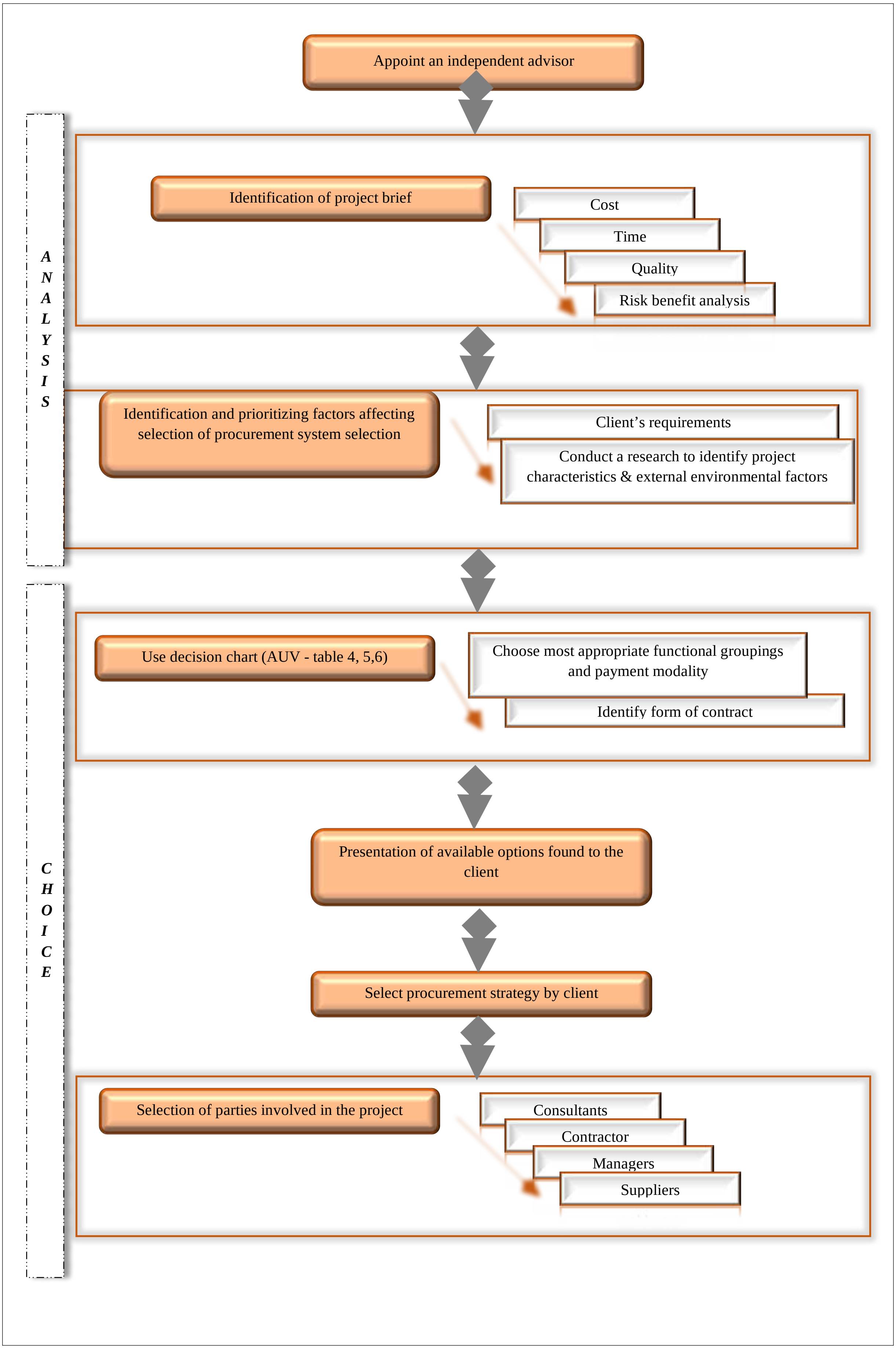

Figure 2: The Proposed PSSM

	Selection Criteria	Weight assigned by the advisor (0-10) Wi	Price based				Cost based		
			R-M AUV	AUV×Wi	LS AUV	AUV×Wi	C + PF AUV	AUV×Wi	C + FF
1	Familiarity	5	81.3	406.5	80.2	401	70.4	352	64
2	Price certainty	8	71.6	572.8	76.9	615.2	61.2	489.6	66.6
3	Risk management	10	56.7	567	77.8	778	59.9	599	69.5
4	Flexibility for changes	7	85.5	598.5	66	462	80.8	565.6	81.6
5	Project cost and funding method	4	72.4	289.6	78.7	314.8	63.5	254	65.8
6	Project complexity	8	63.4	507.2	80.5	644	59.1	472.8	51.4
7	Functional grouping	2	82.3	164.6	80.6	161.2	77.1	154.2	70.5
8	Disputes likelihood	8	85.1	680.8	61.7	493.6	71.5	572	73
9	Tendering methods			0		0		0	
10	Economic Condition	8	55.1	440.8	82.3	658.4	63.9	511.2	65.2
11	Tendering time	1	61.9	61.9	86.8	86.8	54.2	54.2	55.9
12	Client experience	0	60.8	0	80.9	0	77.3	0	65.4
13	Value for money	10	50.4	504	77.4	774	32.4	324	38.3
	Total (ΣAUV×Wi)			4793.7		5389		4348.6	
	Rank			2		1		3	

R-M-Re-Measurement, LS-Lump sum, C+PF-Cost plus percentage fee, C+FF-Cost plus fixed fee, GMP-Guaranteed maximum price, Comp-Co

Figure 3: Procurement Decision Chart

7. Conclusions

The research identified that procurement system selection process in SL is rather unstructured and ad hoc. It was verified in analysis through expert opinion survey and identified two steps as, meeting Client and consultant, identify clients' objectives and selection of procurement system by the consultant. The present selection process only considered time, cost and familiarity of procurement system. Furthermore, seven factors were identified as reasons for hesitance of Sri Lankan procurement experts to adopt systematic procurement system selection. Those are; not availability of understandable model, existing models are not prepared for Sri Lankan context, with the experience of experts they can select suitable procurement system within short time period, non-availability or non-awareness about standard documents for other procurement systems other than separated system or design and build systems, existing models only consider about established method but not bespoke methods, government promotes only separated re-measurement system, existing models supports people who has knowledge on procurement system selection but not the clients with lack of knowledge.

Contractor cash flow, financial risk, tendering method, project duration, familiarity, project type, risk management, contract form, price certainty, speed (during Design & Construction) were identified according to their significance level as factors affecting selection of payment method. Familiarity, price certainty, risk management, flexibility for changes, project cost and funding method, project complexity, functional grouping, disputes likelihood, tendering methods, economic Condition, tendering time, client experience, value for money were identified according to their significance level as factors affecting selection of pricing mechanism.

The proposed PSSM. It includes seven steps as, appoint an independent advisor, identification of project brief, identification and prioritizing factors affecting selection of procurement selection, choose functional grouping and payment modality, presentation of options found in step four in ascending order, selection of procurement strategy by the client, and finally selection of parties involved in the project.

In addition to seven steps, for the fourth step procedure of selecting functional grouping and payment modality using MAUT.

8. REFERENCES

Ashworth, A., 2013. Contractual procedures in construction industry. 6th ed. UK: Taylor and Francis.

Bagnall, B., 1999. Tenders and contracts for buildings. 3rd ed. UK: Blackwell Science Ltd.

Balachandran, H., 2014. Sri Lanka country report. In: 20th Asia Construct Conference. Available from: http://www.asiaconst.com/past_conference/conference/20th/Sri%20Lanka.pdf. [Accessed 09 September 2015].

Dorsey, R., 2004. Project delivery systems for building construction. America: Associated General Contractors of America.

Dowd, V., 1996. The effect of economic cycles on the development and use of alternative procurement systems in UK construction industry during period 1965-1995. Journal of Construction Procurement, 2(1), 3-10.

Gamage, I., 2005. Factors affecting construction procurement selection: Study of clients' requirements and project characteristics (Unpublished bachelors dissertation). University of Moratuwa, Moratuwa, Sri Lanka

Gidado, K. and Millar, A., 1992. The effect of simple overlap of stages of building construction on the project complexity and contract time. In: 8th Annual Conference, Isle Man Association of Researches in Construction Management. 307-317.

Gunasiri, S., 1997. The effective of construction procurement methods on project performance (Unpublished bachelor's dissertation). University of Moratuwa, Moratuwa, Sri Lanka.

Jayasena, H., 2009. Factors affecting construction procurement selection: Study of private sector projects vs. public sector projects (Unpublished bachelors dissertation). University of Moratuwa, Moratuwa, Sri Lanka.

Jayasuriya, W., 2010. Trends of construction procurement in Sri Lanka: Priotizing procurement selection parameters (Unpublished bachelors dissertation). University of Moratuwa, Moratuwa, Sri Lanka.

Kelly, J., Morledge, R. and Wilkinson, S., 2002. Best value in construction. Available from: https://books.google.lk/books?id=wh9d9weMCQsC&pg=PA7&lpg=PA7&dq=Best+value+in+construction+reference&source=bl&ots=LhQxnGTQoV&sig=_dEVIwrOwxxHIHTHuBmqKee9iQs&hl=en&sa=X&ved=0ahUKEwiXp_2OmcnJAhUWkY4KHZFSCMUQ6AEINjAE#v=onepage&q=Best%20value%20in%20construc [Accessed 05 October 2015].

Kumaraswamy, M. and Dissanayaka, S., 1997. Synergising construction research with industry development. In: First International Conference on Construction Industry Development, Singapore. 182-189.

Kumaraswamy, M. and Dissanayaka, S., 1998. Linking procurement systems to project priorities. Building Research & Information, 26(4), 223-238.

Love, P., 1996. Fast building: An Australian perspective. In: CIB W-92 Procurement Symposium, South Africa. 329-343.

Love, P., Davis, P., Edwards, D. and Baccarini, D., 2008. Uncertainty avoidance: Public sector clients and procurement section. International Journal of Public Sector Management, 21(7), 753-776.

Love, P., Stikmore, M. and Earl, G., 1998. Selecting a suitable procurement method for building projects. Construction Management and Economics, 16(1), 221-233.

Manley, K., 2008. Against the odds: Small firms in Australia successfully introducing new technology on construction projects. Research Policy, 37(10), 1751-1764.

Masterman, J., 2002. An introduction to building procurement systems. 2nd ed. London: Spon Press.

McDermott, P. and Khalfan, M., 2006. Achieving supply chain integration within construction industry. The Australian Journal of Construction Economics and Building, 6(2), 44-54.

Meteo, J. (2012). Multi-attribute utility theory. In Proceedings of Multi-Criteria Analysis in the Renewable Energy Industry. London: Springer, 63-72.

Miller, G., Furneaux, C., Davis, P., Love, P. and O'Donnell, A. 2009. Built environment procurement practice: Impediments to innovation and oppertunity for changes. Canberra: Curtain University of Technology, Australia. Available from: http://eprints.qut.edu.au/27114/1/Furneaux_-_BEIIC_Procurement_Report.pdf. [Accessed 18 August 2015].

Mortledge, R., Smith, A., and Kashiwagi, D., 2006. Building procurement. UK: Blackwell.

Najeeb, A., 2005. Factors affecting construction procurement selection: Study of External (Unpublished bachelor's dissertation). University of Moratuwa, Moratuwa, Sri Lanka.

New South Wales Construction Policy Steering Commitee. 2000. Capital project procurement manual: Procurement system selection. Sydney: NSW Government.

Ng, S., Luu, D. and Chen, S., 2000. Decision criteria and their subjectivity in construction procurement selection. The Australian Journal of Construction Economics and Building, 2(1), 70-80.

Potts, K., 1988. An alternative payment systems for major 'fast track' construction projects. Journal of Construction Management and Economics, 6(1), 25-33.

Rameezdeen, R. and De Silva, S. 2002. Trends in construction procurement systems in Sri Lanka. Built-Environment Sri Lanka, 2(1), 2-9.

Rameezdeen, R. and Jayasena, E. 2013. Comparing the procurement selection parameters of private and public sector clients. International Journal of Construction Project Management, 5(2), 171-184.

Ratnasabapathy, S. and Rameezdeen, R., 2006. A Multiple Decisive Factor Model for Construction Procurement System Selection. In: Annual Research Conference of the Royal Institution of Chartered Surveyors, 1-12. Available from: http://www.scribd.com/doc/46545611/Multiple-Decisive-Factor-Model-Construction-Procurement-Cobra-2006#scribd [Accessed 02 July 2015].

Ratnasabapathy, S. and Rameezdeen, R., 2007. A decision support system for the selection of best procurement system in construction. Built-Environment-Sri Lanka, 7(2), 43-53.

Sherif, E. and Kaka, A., 2003. Factors influencing the selection of payment systems in construction projects. In: 19th Annual ARCOM Conference, 63-70.

Shiyamini, R., Rameezdeen, R. and Amaratunga, D. 2005. Macro analysis of construction procurement trends in Sri Lanka. In: 5th International Postgraduate Research Conference of the Research Institute for the Built and Human Environment, UK. 525-536.

PROMOTING FLEXIBLE WORKPLACE TO ENHANCE PRODUCTIVITY OF OFFICE WORKER

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ABSTRACT

To improve workforce productivity and to make major cost savings, various innovative workplace concepts are being utilised. A carefully planned workplace can have a significant impact on the performance of an organization. Even though the importance of flexible workplace towards increased productivity has been identified as a vital point in workplace planning and designing in Sri Lankan office context, there is a lack of research done on the enhanced productivity of office workers of public sector offices in Sri Lanka through the flexible workplace approach. Thus, this research was undertaken to study the relationship between productivity level of the employees and the flexible workspace design arrangements of workplace environment. Accordingly, the study was structured with a mix approach to accomplish the aim of this research. Literature revealed that flexible workplace approach relates to the concept of the physical layout and functional opportunities of the workspace which affect the office worker productivity and thereby conceptual framework was developed based on the literature findings. Through the case study approach, study identified the existing workplace practices. Expert survey was carried out to discover barriers, strategies which can be used in Sri Lankan office context when implementing flexible workplace approach. The gathered data were thereafter analysed using N-Vivo (2011) software. Finally, a framework was developed to promote flexible workplace concept in order to enhance productivity of the workers of Sri Lankan public offices. The framework could be useful for designers, planners and real estate developers to incorporate flexible workplace planning in Sri Lankan public office sector.

Keywords: *Employee Productivity; Flexible Workplace; Office Buildings; Workplace Planning and Design.*

1. INTRODUCTION

Employee productivity is an essential element of a company`s success in today competitive business environment (Limor, 2007). Employees who are more satisfied with the physical environment are more likely to produce better work outcomes in every workplace (Lee, 2006). The workplace is a parameter of great importance for an organization, which affects worker productivity (Fassoulis and Alexopoulo, 2015).A carefully planned and implemented workplace and environment can have a thoughtful impact on the performance of an organization (Smith, Tucker and Pitt, 2010).More innovative workplaces may stimulate more innovative work, while helping attract and retain more innovative workers (Haynes and Price, 2004). The necessity to identify the importance of flexible workplace towards increased productivity has been identified as a vital point in workplace planning and designing in Sri Lankan office context.

Comparatively, there are few published researches on flexible workplace planning and design environment. Further, only few studies have addressed the public office sector and no study has been carried out about flexible workplace to enhanced productivity of office workers of public sector offices in Sri Lanka.

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2. LITERATURE SYNTHESIS

2.1. WORKPLACE PLANNING AND DESIGNING

Organisations are seeking ways to enhance their productivity in order to compete with the increasing competition worldwide. Enhancement of office worker productivity depends on several factors (Haynes, 2008; Bluyssen, 2009; Bakker and Voordt, 2010). According to findings of Bakker and Voordt (2010) and Bluyssen, (2009), mainly five factors should be considered by management of the organization to get the best productivity from employees such as Office Design, Management Style, Vision and Strategy, Technology and Downtime. According to research carried out by the American Society of Interior Designers (ASID) (as cited in Steiner, 2006), physical Workplace design is one of the top factors that impact the employee productivity.

According to Haynes (2008) it is most important to consider the Workplace Design contributions such as access to qualified workforce, workplace efficiency, productivity and cost reduction to achieve business objectives. Furthermore, Karen (2004) stated that a lot of organizations will look toward office Workplace Designs that will provide, open, technologically advanced, flexible, comfortable, and secure spaces with all the necessary components to attract and retain high quality employees and maximize productivity. Moreover, employees who are more satisfied with the physical environment are more likely to produce better outcomes in every workplace (Leaman, 1995; Roelofsen, 2002; Lee, 2006).

2.2. FEATURES OF WORKPLACE DESIGN TO ENHANCE PRODUCTIVITY

The American Society Interior Design (ASID) (as cited in Steiner, 2006) indicated that the following four primary areas in which workplace design impact the productivity: Accessibility, Employee comfort, Privacy, including limiting noise and distractions, Flexibility.

Accessibility - Accessibility is essential to provide productive communications within companies and all among workers (Schmidt and Simone, 1996). Hence, people need to move to a one place to another place in office premises to continue such focused affairs. In addition to that, several researches and case studies showed that improved accessibility; help increase productivity, including a clear link between higher density of workstations and higher employee productivity levels. Comfort - According to the ASID (as cited in Steiner, 2006), Comfort level of workplace directly impacts to the worker productivity and there is a positive relationship between employee's comfort level and productivity.

Ergonomics - Ergonomics is becoming a very vital issue in the workplace. Moreover, Gutnic (2007) stated that uncomfortable offices create a big issue by producing a variety of ailments, including headaches and pain and strains on the eyes, wrists, hands, arms, back and neck among office worker.

Lighting - Lighting is a one of the most critical elements in creating a comfortable work environment. According to Shabha, (2006), control of light in buildings is essential to creating an appropriate, effective and efficient working environment and enhanced worker productivity.

Colour - ASID (as cited in Steiner, 2006) realized that colour impacts attitude and comfort level of the employees. Although many research projects have been realized various types of colour impacts effects such as physiological, affective and cognitive on the worker productivity.

Noise and Acoustics - ASID (as cited in Steiner, 2006) found that poor noise level can have a severe impact on a worker’s physical health and psychological well-being.

Indoor Air Quality (IAQ) - The poor indoor air quality causes a range of health problems such as sick building syndrome, workplace stresses (Axley, 1993). Several researchers realized that good indoor air quality is beneficial for health, comfort and productivity (Wargocki, Wyon, Sundell, Clausen and Fanger, 2000).

Furniture - Leblebiei (2012) emphasized that furniture and furnishing is one of the leading physical aspects comfort levels that directly influence the employee’s better productivity. According to the result of several surveys (Gutnic, 2007; Haynes, 2008; Chandrasekar, 2011) furniture and furnishing are the most effective physical workplace environment factors which increases or decrease employee’s productivity.

Privacy - Privacy is defined as “protections from sensory stimuli (auditory and visual) so an individual can concentrate, think, or talk about sensitive issues” (Smith and Kearny, 1994).

***Flexibility* -** According to ASID (as cited in Steiner, 2006 survey respondents, if the organization wants to improve the productivity of their employees, workplace flexibility is a vital concern. They pointed out that flexibility also means designing offices that are adaptable to meet organizational members 'needs and future needs of the organization to stay ahead of market competitors. Through the workplace changes such as providing flexible layout or design, access and privacy organisational flexibility can be improved (Bucki and Pesqueux, 2000).

This implies that due to the emergence of new technologies and the increase in global business competition, organisations need to consider very much about the concept of designing sustainable, flexible workplaces to accommodate various future changes quickly and effectively.

2.3. FLEXIBLE WORKPLACES

Implementing flexible workplace arrangements positively affect the quality of employees' personal lives. It will also help employers to improve the productivity and efficiency of their business and employees to maintain a work-life balance. Designers, developers, investors, facilities managers and planners always try to provide sustainable and flexible workplace facilities, where flexibility relates to the concept of the supple physical layout of the workspace (Bucki and Pesqueux, 2000; Bell and Anderson, 1999; Becker, 2002; Hassanain, 2006). Four major areas can be identified under flexibility concept in WPD as;

***Planning of the building* -** When concerning the life cycle of the building, it is important to design for adaptability for alteration of the building which can be occurred in the future. According to the NCPP (2004), the adaptability of a building depends on requirements of building occupants, changing needs of occupants, work processes and layouts.

***IT Networking* -** Technology is a major power of work and a fast driver of workplace design and strategy. Whenever companies that expect to improve in the future of workplace technology should start planning now if they want to compete in the future with flexible workplace arrangements with involvement of innovative technology.

***Building service systems* -** Flexible building services should be able to support the operational necessities while responding to the changing requirements of an organization. Building service systems include Heat Ventilation and Air Conditioning (HVAC) systems, Lighting, Electrical systems and Water supply systems.

***Layout of the physical workplace* -** According to the Hassanain (2006), workplace layout refers to an arrangement of everything needed for production of goods or services. Furthermore, the interior of a workplace layout should be designed to mainly focus their workers' requirements. It results in productivity of the workforce positively.

The next section explains the research method adapted to carry out the study.

3. RESEARCH METHODOLOGY

An extensive literature review explored flexible workplace planning and designing factors which affect the employee productivity. Afterwards, a mix approach was employed to establish the development of a flexible WPD approach for Sri Lankan public office buildings. In the first stage of data collection, the researcher obtained a comprehensive knowledge regarding the WPD practices in Sri Lankan public office sector. With the assistance of first stage information, the interview guidelines for second stage were developed.

Three cases were selected with the purpose of collecting data for this study. Three executive managers and 12 staff workers from each case were selected for carrying out interviews and questionnaire survey in selected three cases. The interviews were conducted with the relevant managerial level individuals of the respective case. Employee assessment survey was used for this study since it involves measuring office worker satisfaction level on workplace arrangements in related to WPD approaches, consists with 12 respondents from each selected Cases who are selected using convenience sampling. The five point (1-5) Likert scale was used to collect employees' responses and the composition of the questionnaire was designed with five sections with aid of literature findings. Hence, second stage data collection process consists with the expert opinion survey.

The composition of the questionnaire was designed with five sections identified from literature synthesis as having a significant impact on flexible workplace planning and designing including Furniture, Noise level, Temperature, Lighting and Spatial arrangement. Further, the existing practises and comfort level on the workplace design relating to selected three Cases, expected by the employees in the office. In order to evaluate the likely occurrence of a certain event, mean weighted rating method can be adopted. The MR equation which has been used in this research study is:

$$Mean\ Weighted\ Rating = \frac{\sum (Vi \times Fi)}{n} \qquad (Eq.\ 1)$$

Where,

Vi = Rating for each factor

Fi = Frequency of responses

n = Total number of responses

The mean weighted rating for each factor was computed to deliver an indication of the “Satisfaction” level for each factor in the questionnaire survey. According to the analysis the factors, the factors which gained value below than 2.5 for the MR were taken as unsatisfied factor and greater than 2.5 for the MR were taken as satisfied level of each factors as the midpoint is 2.00 in three-point scale.

Expert survey was undertaken to investigate the strategies those can be applicable to Sri Lankan context. Interviews were conducted with five industry experts who are well experienced and engaged in Sri Lankan design industry using semi structured interviews. Content analysis using N-Vivo 2011 was used in data analysis. Finally, the conclusions and recommendations were drawn based on all findings of the research.

4. DATA ANALYSIS AND FINDINGS

Research findings arising from the three case studies and expert surveys are presented and discussed in this section.

4.1. FINDINGS OF THE CASE STUDIES

All the interviewees of the three cases strongly agreed without any hesitation that in a competitive business environment, achieving worker productivity is an essential part. When it comes to role of WPD, employees who are more satisfied with the physical office environment tend to produce better outcomes in every workplace. Based on manager’s experience and observations opinions most of the workplace environmental factors have an impact on worker productivity in office sector. As per the knowledge of different experts, respondents of the three cases are also strongly agreed that Accessibility, Comfort, Privacy and Flexibility are directly impacting on workplace environment due to different reasons. Apart from that, four respondents agreed that indoor air quality mainly impacts for the workers' mental fatigue and sick building syndrome and another two respondents stated that for future expansions and for achieving relaxing working environment flexibility factor has a direct impact. When addressing the issues of existing practices of workplace planning arrangements, each respondent emphasized on different practices in some cases with overlaps.

When summarizing the findings of literature review and the case studies, it was obvious that there are issues in existing WPD arrangements of physical layouts in public office building in Sri Lanka. Further, the employee satisfaction level of existing WPD arrangements of physical layout were identified during the case studies.

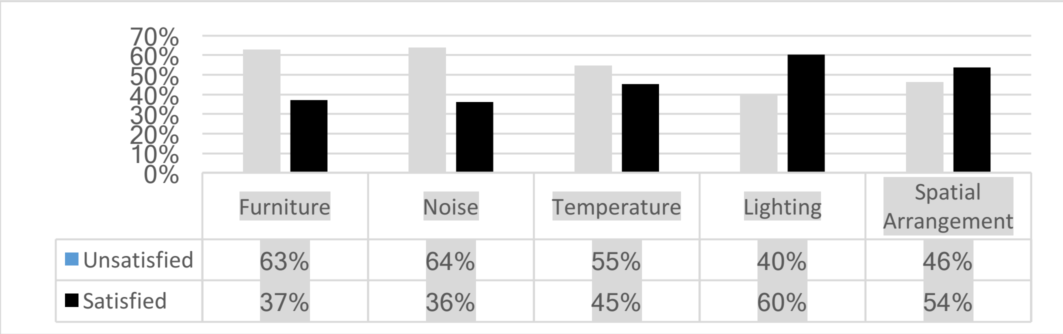

Figure 1: Overall Employee Satisfaction level

As depicted in Figure1, the employee satisfaction on noise level is % which validates the managers' views on poor noise level, such as loud background noise especially in public office day and machines and equipment in the workplace due to poor sound insulation procedure. As well as all the offices are arranged open office concepts excluding executive's cabins. For executive managers, every organization related to select cases used partition walls to prevent the excessive noise but those partition walls are not fully covered. Therefore, all of them which relating to all three cases are mentioned that they are not satisfied about their workplace noise level. This result indicates that those factors contribute for the employee dissatisfaction on WPD significantly. Considering the furniture arrangement, the overall satisfaction level is 37%, therefore the factors which contributing for poor furniture arrangement such as poor chairs, no adequate desks and cupboards are also contribute significantly for the employee dissatisfaction on WPD. The satisfaction on temperature level indicates as 45%, where factors like adequate ventilation again contribute significantly for the employee dissatisfaction. However, lighting and special arrangement indicate higher satisfaction level comparing with the noise, furniture and temperature satisfaction levels. As Figure depicted lighting achieved 60% of employee satisfaction level. This makes the reasons for poor lighting level such as day light requirements not much significant. Similarly, special arrangement achieved 54% of employee satisfaction level where factors like separate and adequate space for relaxation facilities, separate reception and waiting area and separate common desk for emergency activities are not much significant. According to the findings of case studies, various workplace arrangements issues prevail in public offices in Sri Lanka. Identified issues are briefed in Table 1.

Table 1: Identified Issues of Workplace Arrangements

Factors	**Identified Issues**		
	Case A	Case B	Case C
Accessibility (access to the nature view)	No Disability access	Walkways, corridors are used for temporary storage	Corridors are used for temporary storage
	No sufficient space for corridors pathways	Block emergency exits	No facilities to access the nature in free time
	No facilities to access the nature in free time	No facilities to access the nature in free time	
Comfort			
Thermal comport	Too cold in the office	High temperature within an office	Some areas are too cold in the office
		High humidity can create a warm atmosphere	Some areas are too hot in the office
Lighting	Glare in a work area	Poor lighting level	Glare in work area
		No sufficient numbers of light bulbs	
		Very limited natural lighting use in day time	
Colours	Use dark colours for walls.	Use dark colours for walls.	Use dark colours for walls.
Noise	High background noise within the office	High background noise within the office	High background noise within the office

Factors	Identified Issues		
IAQ	Malfunctioning of air handling systems.	Malfunctioning of some fans.	Malfunctioning of air handling systems.
	Poor ventilation.	Poor ventilation.	Poor ventilation.
		No fresh air (SBS)	
Furnishing	No adequate separate space for relaxation facilities	Limited personal space	limited number of benches provide for customers
	Limited personal space	No adequate separate space for relaxation facilities	Limited personal space
		No sufficient paper storage cupboards	No adequate separate space for relaxation facilities
Privacy	Upper level managers have high privacy with rooms and employees have a disturbance due to connection difficulties	No separate partition at least division wise	Half partitions are used to divide workstations
Flexibility	Lack of meeting rooms as employees have to waste lots of time	Zero flexibility facilities as limited space	Lack of meeting rooms as employees have to waste lots of time
			No control how workstation is set up and organized to meet their variety of tasks they perform

4.2. FINDINGS OF EXPERT SURVEY

All these respondents agreed that WPD concept plays an important role in an office building. R3 and R4 agreed that "if the office is an appealing place, physically as well as mentally, then only the management can get a productive workforce". As mentioned by the R2 "the person who are working in the workplace more than 08 hours, he or she must be physically comfortable required for doing work correctly and quickly". According to the R1 expert opinion, "due to lack of space, both over utilization and underutilization cause less productivity. Overutilization may increase the crowd, whereas the underutilization may generate lesser revenue per square feet". Hence it has directly affected the productivity.

However, main categories of workplace environmental factors in an office building are identified in the literature synthesis as follows and gathered data from interviews disclose the importance and strategies carried out under the following categories.

- Accessibility
- Comfort Level
  - Ergonomics
  - Lighting
  - Colours
  - Noise and Aquatics
  - IAQ
  - Furnishing
- Privacy
- Flexibility

All respondents agreed that workplace environmental factors, including Accessibility, Comfort Level, Privacy, and Flexibility are directly impacted to the worker productivity. According to the empirical data reviled that Flexible workplace place will change either based on the user requirements or organizational requirement. Further observed to "Flexible concept and taking actions to mitigate space wastage in office workstations by adhering to practical scenarios which adds value to the worker productivity". All the respondents clearly mentioned that enhanced staff productivity due to the improved internal environment and improved efficiency of energy consumption are the main reasons for that. When considering gathered data on flexible approach for physical layout of workplace, today in every workplace there is more concern on flexible arrangement due to enhanced productivity, improved efficiency and cost effectiveness. When it comes to flexible WPD strategies, they explained that “before set the workplace strategy, it is important to identify the challenges the company faces, factors driving its success and the forces determining decisions”. After that, easily the designer can recognize strategies which are help resolving the workplace issues and achieve better business results. Further, Table 2 findings the flexible workplace designing strategies according to the existing workplace arrangement issues in the Case study`s findings.

Table 2: Flexible Workplace Designing Strategies

Factor	**Remedies/ Strategies**
Thermal comfort and temperature	Provide zoned temperature controls
	Individual controls in each enclosed space such as offices, conference rooms, etc.
	Provide open able windows.
	Close drapes, blinds and shades to keep the sun's rays out of the building during the warmer periods of the day
	Regulate air conditioning for temperature and humidity
	Avoid locating workstations directly in front of or below air conditioning outlets
	Control direct sunlight (radiant heat) with blinds, louvers and window treatments (apply sun control films)
Access to Nature, views and Daylight	Finding a way to introduce opening to the environment and to get day light in whenever possible
	Give nice views to shared spaces
	Maximize the daylight in to the building
Color	Identify suitable colours for various types of work and mental status
	Use appropriate colours to appropriate spaces.
Noise control	Provide individual headsets
	Use a layout which separates noise generating activities
	Isolate noisy equipment such as printers or photocopiers by placing them in separate rooms
	Use sound-absorbent materials, including suitable floor coverings, wall panels, ceiling panels and dividing screens
Human factors and Ergonomics	Provide flexible furniture
	Provide footrest
Indoor Air Quality	Add plants to the office to help clean the air
	Avoid toxic carpets/paints and etc.
Furniture Arrangement	Provide proper divisions by using tress or some natural barrios.
	It should have a supportive backrest that is adjustable in height, angle and depth.
	Storage facilities such as lockers, filing cabinets, and shelves need to be locating on the border of a walkway

However, all explained that “flexible workplace arrangements are practicing in the public office sector in an ad-hoc manner which they have derived, would limit the real benefits connected to the strategies”. Therefore, promoting flexible workplace arrangement strategies heavily affected to enhance productivity. The key findings of the research are summarised under this section in order to set up conclusions and recommendations.

Based on the findings of the study, a framework was developed to promoting flexible workplace to enhance productivity of office worker (refer Figure 2).

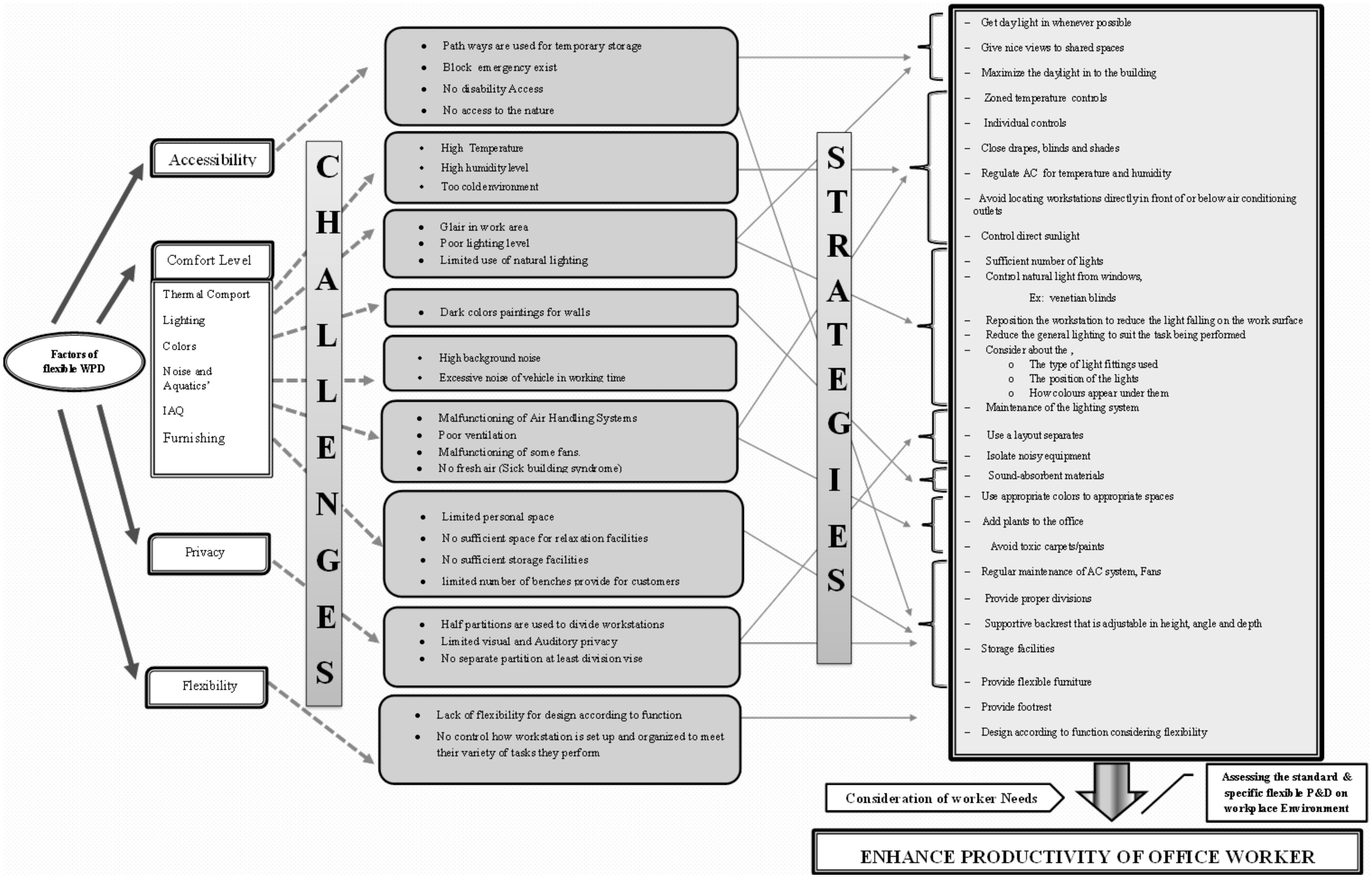

Figure 2: Developed Framework for Promoting Flexible Workplace to Enhance Productivity of Office Worker

5. CONCLUSIONS

The literature revealed that the focusing on the flexible workplace design concept in the office building and basic factors of flexible workplace which affect the productivity of office worker. Through the semi structured interview and employee questionnaire of the selected cases initiated that the existing workplace practices and the challenges that they faced due to the inappropriate physical layout of arrangements under every WPD factors.

Empirical results suggest that workplace physical environment issues including High Temperature, Glair in the work area, Poor lighting level, Limited use of natural lighting, Dark colour paintings for walls, High background noise and Poor ventilation are some identified issues from case study findings. Expert survey findings evidenced how to mitigate recognized challenges in the current office workplace environment. All respondents explained that flexible workplace arrangements are practicing in the public office sector in an ad-hoc manner which they have derived, would limit the real benefits connected to the strategies. Further, findings were revealed that developing a flexible workplace approach frame work, workplace physical layout design has common issues and strategies that have to overcome such issues. Based on the findings, a framework was developed for promoting flexible workplace approach to enhance worker productivity in Sri Lankan Public office sector.

Findings indicate that a significant impact of flexible WPD in public office building on worker productivity. First and foremost, it is necessary to emphasize that, the developed flexible WPD framework is the basis for most of the recommendations to achieve better productivity from workers. Initially, it is recommended to get the assistance of the developed framework to recognize the most appropriate strategies. This research adds to the knowledge of Facilities Mangers as well as other parties who are interested in designing field by presenting a framework related to enhance the worker productivity.

6. REFERENCES

Axley, J., 1993. To help sick buildings recover. *Technology Review*. 96, 12.

Baines, A., 1997. Productivity improvement. *Work Study*, 46(2), 49-51.

Bakker, I. and van der Voordt, T., 2010. The influence of plants on productivity. *Facilities*, 28(9/10), 416-439.

Becker, F., 2002. Improving organisational performance by exploiting workplace flexibility. *Journal of Facilities Management*, 1(2), 154-162.

Bell, S. and Anderson, M., 1999. Workplace solutions. *Journal of Corporate Real Estate*, 1(4), 349-360.

Bluyssen, P., 2009. Towards an integrative approach of improving indoor air quality. *Building and Environment*, 44(9), 1980-1989.

Bucki, J. and Pesqueux, Y., 2000. Flexible workshop: about the concept of flexibility. *International Journal of Agile Management Systems*, 2(1), 62-70.

Chandrasekr, K., 2011. Workplace environment and its Impact on organisational performance in public sector organisations. *International Journal of Enterprise Computing and Business Systems*, 1(1). 1-16

Fassoulis, K. and Alexopoulos, N., 2015. The workplace as a factor of job satisfaction and productivity. *Journal of Facilities Management*, 13(4), 332-349.

Hassanain, M., 2006. Factors affecting the development of flexible workplace facilities. *Journal of Corporate Real Estate*, 8(4), 213-220.

Haynes, B. and Price, I., 2004. Quantifying the complex adaptive workplace. *Facilities*, 22(1/2), 8-18.

Karen, T., 2004. *Trends in office design*. 1st ed. Interiors and Resources. 52-54

Leaman, A., 1995. Dissatisfaction and office productivity. *Facilities*, 13(2), 13-19.

Limor, G., 2007. *A Workplace Design That Reduces Employee Stress and Increases Employee Productivity Using Environmentally Responsible Materials*. Theses (Msc). Master's Theses and Doctoral Dissertations. Eastern Michigan University

Roelofsen, P., 2002. The impact of office environments on employee performance: The design of the workplace as a strategy for productivity enhancement. *Journal of Facilities Management*, 1(3), 247-264.

Schmidt, K. and Simonee, C., 1996. Coordination mechanisms: Towards a conceptual foundation of CSCW systems design. *Computer Supported Cooperative Work (CSCW)*, 5(2-3), 155-200.

Shabha, G., 2006. A critical review of the impact of embedded smart sensors on productivity in the workplace. *Facilities*, 24(13/14), 538-549.

Smith, A., Tucker, M. and Pitt, M., 2011. Healthy, productive workplaces: towards a case for interior plants caping. *Facilities*, 29(5/6), 209-223.

Steiner, J., 2006. The art of space management. *Journal of Facilities Management*, 4(1), 6-22.

Wargocki, P., Wyon, D., Sundell, J., Clausen, G., and Fanger, P., 2000. The Effects of Outdoor Air Supply Rate in an Office on Perceived Air Quality, Sick Building Syndrome (SBS) Symptoms and Productivity. *Indoor Air*, 10(4), 222-236.

Young Lee, S., 2006. Expectations of employees toward the workplace and environmental satisfaction. *Facilities*, 24(9/10), 343-353.

REDUCING ACCIDENTS IN LARGE CONSTRUCTION PROJECTS IN SRI LANKA

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ABSTRACT

Construction industry is considered as one of the leading industries in Sri Lanka, which contributes a significant percentage to the economy. At the meantime, it causes wide range of impact on health and safety of worker. On the other hand, construction industry is well known as an accident-prone industry. Nowadays, large scale construction projects are commonly distributed throughout the world. Hence, it is highly important to ensure proper safety management in the building process with the rising complexity of the projects.

Different types of accidents, contributing factors to the accidents, causes for the accidents and control measure to reduce the accidents were identified through a literature review and it was substantiated through a pilot survey among five safety experts. Subsequently, a questionnaire survey was carried out among the safety practitioner who are involving with construction safety, to assess the pre-identified causes, strategies and mostly occurred construction accidents. A quantitative research analysis was carried out to assess the factors which are assess through pilot survey. Specially, RII was used for data analysis to prioritize the factors and one sample t-test was carried out to identify the significant factors by using SPSS. Finally, the analysis results were used to develop the framework. Sixteen different types of accidents, thirty-four causes for the accidents and thirty-five control measure/ safety practices were identified in this study. Among them seventeen causes and nineteen control measures were finalized as critical factors and those factors were used to develop final framework in order to mitigate the accidents in large construction projects in Sri Lanka.

Keywords: *Construction Safety; Construction Site Accidents; Framework; Large Construction Projects; RII; Sri Lanka.*

1. INTRODUCTION

Construction is generally known as the process of formation of physical infrastructure, superstructure and related facilities (Bertelsen and Koskela, 2004). Construction industry is referred as major part of an economy growth of a nation and generally considered to be the driving force of economy in developing nations. Contribution of construction industry to the main economic factor, Gross Domestic Product (GDP) of a country ranges from 7% to 10% in developed countries, whereas it ranges from 3% to 9% in developing countries (Lowee, 2003). In Sri Lanka, it gives 6.8 % of contribution to GDP, which shows a considerable size of impact to Sri Lankan economy. Therefore, most of the countries are considering construction industry as an important sector. Even though construction industry flourishes the country's economy, it is also considered to be most hazardous in terms of degree of injury and lost time of work caused by it (Dembe *et al*., 2008). Further, construction sites are widely known for its occupational hazard and risk of work, which classifies this line of work to be one of the most dangerous activity on earth (ILO, 2005). Therefore, occupational safety and health have always been sensitive issues in the construction industry, particularly considering its high number of accidents. However, Sri Lanka is considered to be one of the vulnerable country, and is ranked at a little level for occupational Safety and health (OSH) performance due to lack of improvement in safety practices (Gunawardena and Priyangika, 2005). Therefore, this study aims to develop a framework to reduce the accidents in large construction projects in Sri Lanka.

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2. DIFFERENT TYPES OF ACCIDENTS WHICH OCCURS IN CONSTRUCTION PROJECTS

“An accident is an unplanned, undesired event, which may or may not result in injury or property damage that interferes with the completion of assigned task” (Lancaster *et al*., 2003). Accidents are classified into different types in construction industry, hence, there can be many kinds of accidents in relation to their classification the degree of severity of an accident varies according to the classification of such accidents (Rameezdeen *et al.*, 2003). Ferret and Hughes (2007) classified accidents in the construction industry as fatal and non-fatal (major and minor injury). Further to him, accidents in construction industry occurs at work sites and most common accidents and injuries are slips, trips and falls from the same level of work and from separate levels (from higher levels), being hit by moving or falling objects (falling debris), blunt force trauma due to impact on stationary objects, cuts due to sharp objects, abrasions due to rough surface, electrical hazards.

Occupational injuries from construction activities in general are defined by Davis and Tomasin (1990) as: danger of physical injury and fatality; and health problems. On the other hand, Hinze (2002) identified eight group of construction accidents resulting in physical social injuries and fatalities. They are, fire explosion, power tool accidents, excavation related accidents, struck by moving objects, struck by falling object, falling from height, electrical accidents and others (lighting strike, oxygen confined spaces).

3. CAUSES OF ACCIDENT IN LARGE CONSTRUCTION PROJECTS

Every accident occurs as a result of several underlying causes and originate via a source. Therefore, having a clear understanding about those causes of accidents are crucial to develop the proper platform for health and safety management, in order to minimize the causes of accident and relevant costs. When those causes are understood, it will let to take corrective actions to avoid the recurrence of accident and take preventive actions to prevent the occurrence of accident again. Generally, there are two types of factors resulting the accidents, i.e. behavioural and environmental factors. Behavioural factors comprising attitudes, skills, behaviour and knowledge while environmental factors comprising workplace hazards and procedures which causing injuries (Taylor *et al.,* 2004).

Most of the research studies of construction accidents are focusing on causes, consequents of those accident. Broadly those accident’s causes consisting of worksite management and culture; training and competency level of workers; their attitude and behaviour; condition of equipment; improper working procedures; lack of safety regulations and legislation and environmental condition (Gibb *et al.,* 2006). Accidents are originated from lack of awareness of managers on safety, lack of training, incautious operations and fear to commit resources for safety. Further, Rahim *et al.* (2008) found that inexperienced workers and lack of understanding about the construction accidents and relevant risks are the main causes for the accidents and risks on constructions. Further, survey identified unsafe method of operations, which consisting of incorrect and disobeying procedures and the poor knowledge level are the major causes for the frequent occurrence of construction accidents. While construction accidents are take in place result of improper training, deficient enforcement and regulation of safety, lack of safety equipment, improper equipment handling, unsafe working conditions, not using provided safety equipment and poor attitude towards safety are considered as reasons for the accidents on construction site by Toole (2002).

4. AVAILABLE STRATEGIES/ CONTROL MEASURES TO REDUCE THE ACCIDENTS

Number of strategies applied to prevent the construction accidents, those focused depend on technical, organizational and human factors, with many prevention strategies focused on particular accident, the construction company when prevent the particular accident which affect the level of emphasis and resource allocation across various factors (Lancaster *et al.*, 2003). To improve the work place safety, it can prevent those accidents and also it helps to analyse, how these accidents and injuries are generated. Rameezdeen *et al.* (2003) developed an accident prevention programme, which indirectly implicate to productivity and quality, as work procedures are better organized and free from unnecessary intrusions. Further, they expressed that a successful accident plan scheme is required accompanying four fundamental exercises, i.e. a risk assessment to investigate the risk available on the sites, study of operating practices and techniques, provide specialized training, incentives and guidelines and carry out accidents investigation to minify recurrences. In any kind of health and safety management program, the first step could be to identify the hazards or disaster situations in the work environment and place. In this sense, a detailed evaluation and a critical analysis of accidents in the construction industry is of immense importance (Rameezdeen *et al.*, 2003). Furthermore, the importance of health and safety risk management of the construction projects has repeatedly been shown to save lives, time, and money, and to increase business goodwill and good protection (Kikwasi, 2010).

5. RESEARCH METHODOLOGY

The research was structured in several steps. First, the existing literature were reviewed preliminary discussions were held with five (05) safety practitioners who has experience more than 10 years and final questionnaire survey was conducted to find the OSH strategies to formulate the questionnaire and framework development. Majority of the questions in the questionnaire were included with 1 to 5 Likert scale. The remaining questions were included with short answer “yes” of “No” answers. First section of the questionnaire was used to identify the general information on the respondent organization. Section two consists general information of respondents. Further in the third and fourth sections, gathered information on different types of accidents and causes for the accident on construction sites. The last section was focused on the strategies to mitigate the accidents on large construction sites.

The survey sample was included Safety Managers, Safety Officers, Safety Engineer and Safety Consultants from list of large building construction projects. The snow ball sampling under non-probability sampling method was used to determine the sample. A list of all CS2 and CS1 contractors were selected from the CIDA (Construction Industries Development Authority) contractor’s grade listing. For the main survey, respondents were selected from larger construction projects, who are currently involved with safety management practices. Totally 50 respondents were asked to voluntarily complete their particular questionnaire using 1 to 5 Likert scale and 36 responses were returned out of 50 questionnaires.

Prior to the main survey a pilot survey is always recommended to improve the validity and reliability of questionnaire. Pilot survey result was obtained by using Relative Important Index (RII). In order to get relative ranking of the factors.

The final questionnaire was developed after the expert comments and the following changes were made:

- Addition of one cause that were most significant to reduce the construction accidents and deduction of five irrelevant causes from the questionnaire
- Deduction of five least significant strategies from the questionnaire

The one addition was “lack of monitoring and supervision” and the deductions were “Complexity and the diversity of site, in adequate visibility, reckless operation of system, continues changing work site and deficient knowledge of project manager on safety of construction site”. Those were eliminated due to irrelevant to direct causes and it’s related to other listed causes. Finally, 30 causes were selected for the final questionnaire. The five strategies were deducted due to their least practices by construction industries. They were guarding system for machinery, first aid training, and proper permission prior to do the task, insurance policy and training for protecting site when any accident happens. Finally, 30 strategies were elected for the final questionnaire.

6. DATA ANALYSIS AND FINDINGS

6.1. RANKING OF MOST FREQUENT OCCURRED ACCIDENTS IN CONSTRUCTION SITE

Respondents were asked to mention about the types of accidents that were occurred in their own sites. Results were obtained after the analysis and shown in Figure 1.

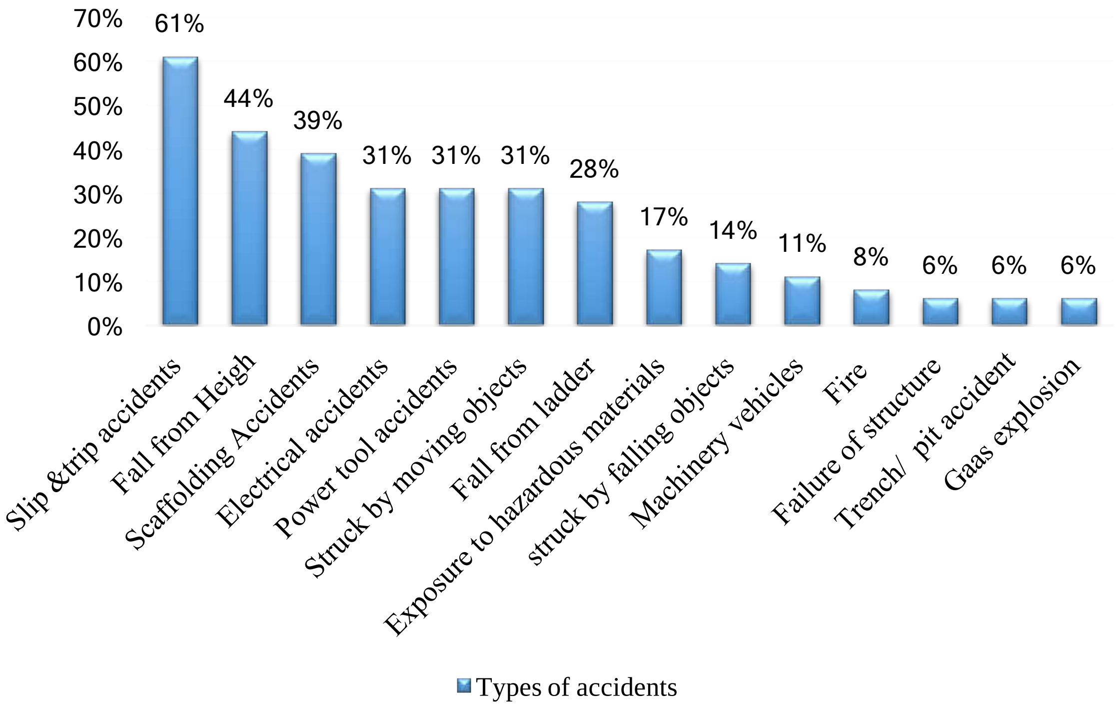

Figure 1: Most Common Types of Accidents in Percentage with Ranking Order

6.2. RANKING OF CAUSES OF ACCIDENTS FOR THE CONSTRUCTION PROJECTS IN SRI LANKA

The respondents were asked to rate the degree of agreement and disagreement on scale using 1 to 5. The relative importance index (RII) test was used as a tool to prioritize the factors both the causes and strategies. After the prioritizing one sample t-test were carried out in order to assess the most critical factors.

Table 1: One Sample t-test and RII Value After Prioritized the Causes of Accidents

No	Factors on causes		RII	Rank	t-value	Significant
1	Management related factors	Non-implementation of rules & regulation	0.94	1	21.76	Yes
2		Limited funds for safety management	0.68	16	2.02	Yes
3		Inadequate policy & standards	0.87	4	8.64	Yes
4		Inadequate safety precaution & procedure for the assigned job	0.90	2	12.21	Yes
5		Not enough rest time during the task for workers	0.77	12	4.51	Yes
6		Deficient knowledge & unqualified officers	0.84	8	8.72	Yes
7		Safety items/tools/Resources are not available on site	0.85	5	9.74	Yes
8		Misuse or Correct tools are not used for the task.	0.64	18	1.31	No
9		Lack of appreciation after completion of task by workers	0.51	26	-3.22	No
10		No training program for workers/ Lack of weekly safety meeting	0.83	9	7.97	Yes
11		Lack of monitoring & supervision	0.84	7	8.47	Yes
12		Lack of top management commitment	0.85	5	10.24	Yes
13		No safety officer at site	0.79	11	6.34	Yes
14		No unity among job crew / no cohesiveness	0.63	19	0.84	No
		Average RII for management related factors	***0.78***			

No		Factors on causes	RII	Rank	t-value	Significant
15	Workers related factors	Lack of knowledge by workers	0.87	3	9.08	Yes
16		Some workers are sufficient from health problems	0.53	22	-2.09	No
17		Due to Fault and misjudgement of workers	0.56	21	-0.98	No
18		Workers are over confident	0.71	14	4.34	Yes
19		Workers willing to take overtime	0.50	27	-3.41	No
20		Workers avoid to wear personal protective items	0.66	17	1.76	Yes
21		Physical fatigue (Tired)	0.53	22	-1.78	No
22		Work load over physical capabilities of workers.	0.68	15	2.86	Yes
23		Quick working (Work is performed while rushing)	0.48	30	-3.32	No
24		worker's attitudes and behaviour	0.62	20	0.43	No
25		Some workers are suffering from mental fatigue on the job	0.62	29	-3.16	No
		Average RII for workers related factors	***0.614***			
26	Project related	Worker have no satisfactory with the nature of the job	0.51	25	-2.93	No
27		Hazards / risk available in the site	0.81	10	6.55	Yes
28		Extreme weather condition	0.49	28	-3.08	No
29		Inadequate housekeeping	0.53	22	-1.67	No
30		Deficit welfare facilities for the workers (House, foods & transportation)	0.74	13	4.86	Yes
		Average RII for project related factors	***0.616***			

6.3. RANKING OF MOST SUITABLE SAFETY STRATEGIES

Table 2 shows the RII values and the rankings status of each factors and the results of the t-test for the factors influence on "strategies for mitigate the accidents" among all the respondents. After the t-test value there are nineteen strategies were identified as significant.

Table 2: One Sample t-test and RII Value after Prioritized the Strategies for Accidents

No	Factors on strategies	RII	Rank	t-value	Significant
1	Pre-project / Pre-task Planning	0.95	1	23.90	Yes
2	Safety orientation and specialized training	0.89	5	11.998	Yes
3	Safety incentives, reward and Punishment	0.86	9	10.345	Yes
4	Drug and alcohol testing	0.42	30	-5.01	No
5	Conduct the accidents investigation after happening the accidents	0.86	8	12.548	Yes
6	Top Management commitment	0.91	2	12.705	Yes
7	OSH management policies, standard & set targets	0.84	11	10.163	Yes
8	Safety audits or inspection	0.89	5	13.506	Yes
9	Employee involvement and empowerment towards safety management	0.84	12	7.78	Yes
10	Safety equipment & supportive devices (PPE)	0.88	7	9.06	Yes
11	Follow check list related to safety measures	0.55	24	-1.19	No
12	Adequate maintenance for equipment	0.67	18	1.82	Yes
13	Resource availability to address the health and safety problem	0.57	23	-0.86	No
14	Proper documentation of OSH issues	0.54	26	-1.53	No
15	Arrange the site environment- (Clean up)	0.55	24	-1.19	No

No	Factors on strategies	RII	Rank	t-value	Significant
16	Use skilled workers to prevent accidents	0.69	17	3.83	Yes
17	Sub-contractor’s management for contribution to accident prevention	0.70	16	3.41	Yes
18	Implement occupational Health and Safety Act and Regulations	0.86	9	9.84	Yes
19	Upgrade the constructions worker’s education for understand the importance of safety.	0.90	4	13.748	Yes
20	Adequate storage for hazardous material	0.53	27	-1.61	No
21	Budget allocation for the safety and health	0.67	18	2.32	Yes
22	Dedicated safety officers in your projects	0.76	15	5.39	Yes
23	Safety administration and Welfare of labour force	0.53	29	-1.77	No
24	Emergency procedure	0.61	20	0.13	No
25	Safety communication & decision making	0.79	14	8.37	Yes
26	Adequate supervision, Safety monitoring and control for workers	0.91	3	15.057	Yes
27	Accident recording and reporting (fatal & Non- fatal)	0.57	22	-0.75	No
28	Job hazard analysis / risk assessment	0.82	13	8.12	Yes
29	Management safety training	0.53	27	-1.61	No
30	Supportive work environment/ safe environment	0.59	21	-0.27	No

7. CONCLUSIONS

The construction industry contributes to the national economy by considerable amount which has high amount of accidents record than in other industries. A Construction site can be considered as hazardous environment due to its complexity and temporary nature. Further, health and safety consideration is always ignored than in product oriented industry. Therefore, there is high demand on safety management on construction industry. In Sri Lanka, many accidents are happening on site, but not reported. These have an adverse effect on a countries economy. The purpose of this research study was to develop a framework to reduce the accidents in larger construction projects in Sri Lanka.

The proposed framework can be used to reduce accidents and it shows a path to create a safe culture in constructions sites. First identification of contribution factors/facts which creates an accident. These contributing facts and factors can be assessed to identify their direct and indirect impact through impact assessment. Where impact is higher the accident preventive measures shall be taken. These can be reflected and be included in policy statements and objectives of an organization. When an accident happens again factors/causes can be identified as per its type through detailed investigation. The identified causes should be recorded to identify direct and indirect impact of accidents. Then reactive measures/control measures can be taken. The feedback should go through policy statement by comparing the pre-identified contributing factors for accidents and find root causes for continues improvement. Through feedback, the proactive control strategies need to revise. The framework is shown in Figure 2.

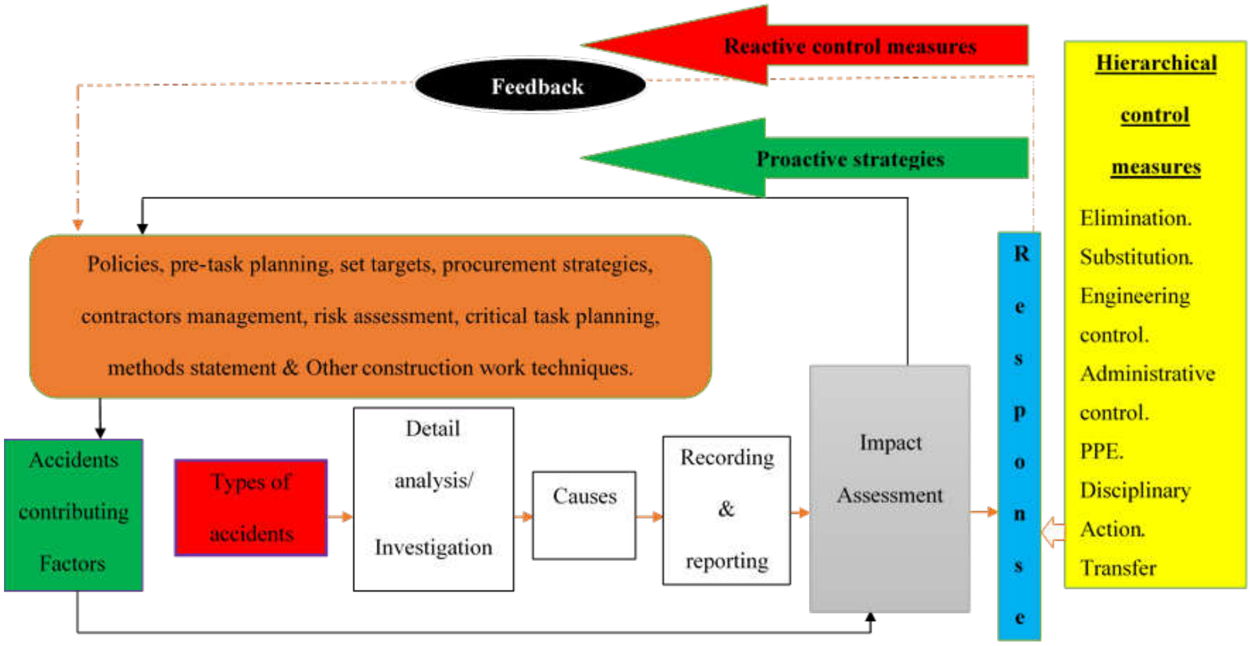

Figure 2: Most Common Types of Accidents in Percentage with Ranking Order

8. REFERENCES

Bertelsen, S. and Koskela, L. 2004. Construction beyond lean: a new understanding of construction management. In *12th annual conference in the International Group for Lean Construction*, Elsinore, Denmark, 1-11.

Davis, V. and Tomasin, K. 1990. *Construction Safety Handbook.* London: Thomas Telford.

Dembe, A., Delbos, R. and Erickson, J. 2008. The effort of occupational and industrial on the injury risk from demanding work schedules. Journal of Occupational and Environmental Medicine, 50(10), 1185-1194.

Ferret, E. and Hughes, P. 2007. *Introduction to health and safety in construction*. 2nd ed. UK: UK-Elsevier Ltd.

Gibb, A., Haslam, R., Gyi, D. and Duff, R. 2006. What causes accident? *Civil Engineering*, 159(6), 46-50.

Gunawardene, N. and Priyangika, L. 2005. Minimizing construction accident through the integration of safety practices into ISO 900 Quality requirement. *Built Environment*, 5, 228-233.

Hinze, J., 2002. *Safety Plus: Making Zero Accidents A Reality*. CII Research Report 160–11. March 2002, University of Texas at Austin, Austin, Texas. Gainesville, pp. 110

ILO. 2005. *Guidelines on occupational safety and health management system*. International Labour Organizations.

Kikwasi, G. 2010. Client involvement in construction safety and health. *Journal for Building and Land Development*. Ardhi University.

Lancaster, R., Ward, R., Talbot, P. and Brazier, A. 2003. *Cost of compliance with health and safety regulation in small and medium enterprises*. London: SK.

Lowee, J. 2003. *Construction Economic.* 2nd ed. London: King ling Publisher.

Rahim, A., Hamid, A., Zaimi, M., Majid, A. and Singh 2008. Cause of accidents at construction sites. *Malaysian Journal of Civil Engineering*, 20(2), 203-210.

Rameezdeen, R., Pathirage, C. and Weerasooriya, S. 2003. Study of Construction Accident in Sri Lanka. *Built Environment*, 4(1), 27-32.

Taylor, G., Easter, K. and Hedney, R. 2004. *Enhancing occupational safety and health. Oxford*: Elsevier Butterwoth Heinemann.

Toole, T. 2002. Construction site safety role. *Journal of Construction Engineering and Management*, 128(3), 203-210.

REVISITING CAUSES OF DISPUTES: PERSPECTIVES OF PROJECT PARTICIPANTS, PHASES OF PROJECT AND PROJECT CHARACTERISTICS

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ABSTRACT

Dispute management is a proactive way to avoid disputes beforehand and resolve them effectively once disputes have materialised. Thus, dispute management should begin at early stage of project where different project characteristics are originated. On this note, the current research revisits the causes of disputes from different perspectives; project phases, project participants, and project characteristics. A comprehensive literature review was carried out by referring key research papers and books in the areas of disputes and related issues. Firstly, a total of 50 causes were identified and analysed using frequency count in order to identify the significant causes of disputes. Secondly, those causes were sub-themed into project participants, phases of project and project characteristics. The research revealed that the causes of variations, inadequate/incomplete drawings and specifications and payment delays are the most significant causes of dispute. Further, the research found that contractor is responsible for the variations and poor quality of work during construction stage of a project. The consultant is responsible for inadequate/ incomplete drawings and specifications which occur during design and tendering stages. Client mainly responsible for payment delays during construction stage of a project and scope changes throughout the project. Thus, the identified causes have further clustered under project phases and responsible parties. The consultant, contractor, and client are contributing to disputes in terms of 11, 7 and 6 numbers of causes respectively. The study found that there is link between the key project characteristics and causes of dispute. Thus, the research identified around eight key project characteristics have influenced in certain causes of disputes. Thus, the review concludes that the disputes need to be addressed in every stage of construction project and by each party to contract. In addition, the review recommends that there is possibility to manage disputes through the view point of project characteristics at the early stage of construction projects.

Keywords: *Causes; Dispute; Project Parties; Project Phases; Project Characteristics.*

1. INTRODUCTION

As evidenced in the range of studies, disputes are prevalent in today's complex and competitive construction environment. For example, Cheung and Yiu (2006) highlight that the likelihood of dispute occurrence in traditional complex projects is almost equal to 1.00. Therefore, Chong and Zin (2012) indicated that conflicts being unresolved between parties result in disputes in construction projects. Moreover, construction disputes vary in nature, size and complexity, though they all have a common threat. Disputes are costly both in terms of time and money and often affect the working relationships between construction parties (Farooqui and Azhar, 2014). Kumaraswamy (1997) is of the opinion that the relationship between disputes and construction stakeholders are two directional: construction involves many stakeholders and the actions of those stakeholders could lead to conflicts and disputes in construction projects. On the other hand, conflicts and disputes arise due to other reasons affect the performance of the main stakeholders such as clients, consultants, contractors and subcontractors. On a different note, Cakmak and Cakmak (2013) indicated that contractors are mostly responsible for disputes in construction projects.

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Disputes remain as a challenge in the construction industry with the potential danger of project failures in terms of cost and time overruns, and litigation (Cheung and Yiu, 2006; Kassab *et al*., 2010). On a similar note, Cakmak and Cakmak (2013) indicated that disputes are one of the main causes, which prevent the successful completion of the construction project. As the disputes are often lengthy, complex and expensive to resolve, they can cause long term damage to the commercial relationship between the parties (Thobakgale *et al*., 2014). Further, Thobakgale *et al*. (2014) pointed out that the owner may suffer significant loss of profit and worst still the project may be abandoned. Farooqui and Azhar (2014) stressed that when construction disputes are not resolved in a timely manner, it becomes very expensive in terms of finances, personnel, time, and opportunity costs. Authors further explained the expenditure that visible expenses for attorneys, expert witnesses, the dispute resolution process itself, alone are significant. The less visible costs like company resources assigned to the dispute, lost business opportunities and the intangible costs such as damage to business relationships, potential value lost due to inefficient dispute resolution are also considerable.

These range of negative effects stressed researchers to investigate the causes of dispute in order to minimise/manage them systematically. Over the years, many researchers have studied the causes of disputes in different perspectives. For example, Kumaraswamy (1997) investigated root and proximate causes of disputes. Cakmak and Cakmak (2013) classified the causes into several major categories owner related, contractor related, design related, contract related, human behaviour related, project related and external factor related. In Pakistan, Farooqui and Azhar (2014) sought to determine the causes in terms of construction related, financial/economical related, management related and contract related. However, the researchers have less considered the disputes in the perception of management; thus disputes still persist in construction project. Therefore, the research tends to identify the significant causes of disputes and clusters the causes in terms of responsible parties, project phases and project characteristics in order to manage them at the early stage of construction project.

2. RESEARCH METHODOLOGY

According to Fink (1998), literature review is a systematic, explicit, and reproducible design for identifying, evaluating, and interpreting the existing body of recorded documents. Literature review usually aims at two objectives: first, they summarize existing research by identifying patterns, themes and issues. Second, this helps to develop theory (Harland *et al.*, 2006). In this way, the current research reviews the causes of disputes in order to categorise them in different perspectives. Initially the research sought to review the articles related to disputes and the related issues to identify the background of the study. Then, the research investigates the causes of disputes in different perspectives; project parties and stages of project, and project characteristics.

A comprehensive literature review was carried out by referring journal, conference proceedings, books and other reliable sources published in the areas of disputes and related issues such as of causes and effects of disputes, and disputes management. Particularly, the research focuses on the articles, which fall in the span of last two decades. A total of fifty (50) causes were identified and significant causes were sorted using frequency count. The causes were further clustered in terms of project parties, project phases and project characteristics.

3. CAUSES OF DISPUTES

Inevitably, disputes are a reality on every construction project (Steen, 2002). Many researchers have sought to investigate the causes of disputes. Accordingly, Carmichael (2002) and Steen (2002) identified that causation of disputes may fall under three major categories namely: organisational, contractual and technical. Organisational interpreted as increased project complexity has resulted in varying forms of contract, each with varying interfaces where misunderstandings occur giving rise to dispute. Contractual includes the causes of extension of time, liquidated damages, variations, loss and expense, payment, late deliverables, adverse weather and alike while technical comprises poor/incomplete design, workmanship, material selection and alike. On a different note, Mitropoulos and Howell, (2001) addressed the causes of disputes in terms of uncertainty, contractual problems and opportunistic behaviour.

Love et al. (2008) mentioned that one of the key factors that contribute to dispute is unfair risk allocation and poor risk management. Inappropriate risk allocation through disclaimer clauses in contracts is a significant reason for increasing total construction costs. The most common exculpatory clauses used in construction are Uncertainty of work conditions; Delaying events; Indemnification; Liquidated damages; and Sufficiency in contract documents (Zaghoul and Hartman, 2003). Architects specifically lack procedures to control the design process and generally do not implement activities that assure conformance. As a result, design related documentation produced often contains errors and omissions and often leads to contractual claims and disputes. Love *et al*. (2008) mentioned that poor documentation can lead to rework, a delay, and claim for loss and expense by the contractor and subcontractor. Errors can arise because of poor knowledge, carelessness and negligence, and intent of the professionals. A lack of professionalism by design professionals because of reduced design fees can result in inadequate contract documentation being produced, and therefore lead to rework that manifests as a lack of professionalism and may eventually emerge in a dispute (Kumaraswamy, 1997).

In general, interpretation error and misunderstanding of contract terms or clauses can happen. These issues result in disagreements between the contracting parties on their contractual rights and responsibilities. On a similar note, Chan and Suen (2005) mentioned that even though an internationally accepted standard forms FIDIC is used, different interpretations by various parties from the two legal systems, Common Law and Civil Law, may cause misunderstanding and this could way to disputes. Armes (2011) added that misunderstandings about obligations arise from erroneous contract interpretation, or perhaps the documentation has not been clearly drafted. Issues about progress and quality frequently arise and may originate from the different aims each party to the contract will have.

Thus the literature evidenced that there have been considerable researches undertaken to determine the causes of disputes in the construction industry. Although researchers have widely addressed causes of disputes, still disputes exist in construction projects. In this context, it is necessary to address the causes in terms of different perspectives. Thus, the following sections of the paper review the causes of disputes under project parties, stages of project, and project characteristics. Firstly, the current research tends to identify the significant causes of disputes.

3.1 SIGNIFICANT CAUSES OF DISPUTES

This section of the paper furnishes the causes of disputes with the frequency count. A total of 15 key research papers discuss on causes of disputes have been selected for this study. Table 1 shows the top 20 causes of disputes with the frequency count and the respective sources.

Table 1: Significant Causes of Disputes

Causes of Disputes	Frequency Count	Sources
Variation initiated by owner/scope changes	11	[1], [3], [6], [8], [9], [10], [11], [12], [13], [14], [15]
Inadequate/incomplete specification and drawing	11	[1], [3], [6], [8], [9], [10], [11], [12], [13], [14], [15]
Payment delays	11	[1], [3], [6], [8], [9], [10], [11], [12], [13], [14], [15]
Unclear and unfair risk allocation	10	[1], [2], [3], [6], [7], [8], [9], [10, [12], [15]
Poor communication	10	[1], [2], [3], [6], [7], [8], [9], [11], [12], [15]
Poor quality of work	7	[1], [2], [3], [4], [6], [10], [12]
Ambiguities in contract document	7	[1], [3], [5], [7], [9], [11], [12]
Different interpretation of contract provisions	7	[2], [3], [6], [7], [8], [10], [15]
Site conditions	7	[1], [3], [8], [9], [10], [12], [15]
Unrealistic time targets	6	[3], [6], [7], 10], [11], [12]
Design errors	6	[1], [3], [8], [9], [10], [15]
Poorly done planning and scheduling	5	[7], [10], [12], [13], [15]
Unstable financial status of client	5	[1], [4], [7], [8], [13]
Negligence/lack of professionalism	5	[1], [6], [7], [8], [10]
Inadequate contract administration	5	[1], [7], [8], [9], [12]
In competent contractor	5	[1], [4], [6], [12], [13]
Unavailability of information	5	[2], [3], [8], [10, [15]

Inappropriate selection of procurement method	5	[2], [7], [8], [10], [11]
Legal and economic factors	5	[1], [2], [3], [7], [12], [20]
Inadequate brief	4	[1], [5], [8], [15]

[1] Acharya and Lee (2006); [2] Armes (2011); [3] Cakmak and Cakmak (2013); [4] Colin *et al* (1996); [5] Cheung and Pang (2014); [6] Cheung and Yiu (2006); [7] Farooqui and Azhar (2014); [8] Khahro and Hussain Ali (2014);); [9] Kumaraswamy (1997); [10] Love *et al* (2010); [11] Mitropoulos and Howell (2011); [12] Na Ayudhya (2011); [13] Odeh and Battaineh (2002); [14] Yiu and Cheung (2007); [15] Waldron (2006)

Table 1 shows the top most causes of disputes with the respective frequencies out of 15 references. Accordingly, causes of changes to initial scope, inadequate/incomplete specification/drawing and payment delays are identified as most significant factors, which lead to disputes. The authors (Love *et al*., 2010) indicated that frequent changes to scope lead to cost and time overruns and thereby cause disputes. Most change orders that occur are at the request of the client and are generally in the form of design changes (Sinha and Wayal, 2013). However, Sinha and Wayal (2013) pointed out that changes to scope occur not only due to client but also due to stakeholder needs, physical location and the prevailing economic environment.

Inadequate/incomplete specification and drawing is considered by many of the authors. Design issues can lead to delays and additional costs that become the subject of disputes. Often no planning or sequencing is given to the release of design information, which then impacts on progress of work; ultimately it affects the quality of product in the long run. In addition, Love *et al*. (2006) stated that errors in drawings and specification can arise because of poor knowledge, carelessness and negligence of consultant. Poor knowledge is often a result of insufficient education, training, and experience. Many design firms, fail to undertake design audits, verifications and reviews of the documents that they produce prior to tendering, which increase the possibility of errors.

As per Table 1, many of the researchers have concluded that payment delays contribute to disputes in projects. For example, Na Ayuldhya (2011) found that payment delays as one of the most significant causes of disputes in domestic funded projects of Thailand. In addition to that, some authors ascertained the causes of dispute in the UK construction industry, it was indicated that payment problem contribute significantly to dispute in the industry. The integral parts of payment problem originated from many issues: additional work, over budget, basis of fee, additional fees, non-return of retention money, liquidated damages claimed by client, extension of time costs and expenses claimed by contractor, non-payment of balance of contract sum to subcontractor, non-payment of interim payment to subcontractor, non-payment of interim payment to contractor, variation claim by contractor. On the other hand, the researchers such as Chan and Suen, (2005) highlighted that payment issues lead to disputes and subsequent suspension and termination of projects. The authors found that issues of payment as one of the major causes for disputes in the construction industry. In addition, Sheridan (2003) stated that the payment related matters of valuation of variations and final accounts, and failure to comply with payment provisions, are the major subject matters for disputes in construction project adjudication proceedings.

Love *et al*. (2008) mentioned that one of the key factors that contribute to dispute is unfair risk allocation and poor risk management. Inappropriate risk allocation through disclaimer clauses in contracts is a significant reason for increasing total construction costs. As mentioned earlier, the exculpatory clauses of Uncertainty of work conditions; Delaying events; Indemnification; Liquidated damages; and Sufficiency in contract documents are leading to unfair risk allocation in construction contracts. On a different note, in an attempt to examine the causality of disputes, Kumaraswamy (1997) sought to determine the root and proximate causes. The author identified unfair risk allocation as one of the root causes of disputes. Poor communication is identified as significant cause with the frequency of ‘10’. The review revealed that Poor quality of work, Ambiguities in contract document, Different interpretation of contract provisions, Site conditions are considerably significant causes with the frequency of ‘7’. In general, interpretation error, misunderstanding of contract terms or clauses and ambiguities in contract document often happen in projects. Though the standard forms of bidding document used, issues exist in some places. However, consultant is responsible for such document issues while contractor might be in a position to suffer due to the misunderstanding of clauses.

Thus, this section identified the significant causes of disputes. The finding revealed that the different parties; client, contract, and consultant are responsible for different causes. Therefore, the section tends to cluster the range of causes in terms of project parties and project phases.

3.2 *CAUSES OF DISPUTES - PERSPECTIVE OF PROJECT PARTIES AND PROJECT PHASES*

This section of the paper presents the causes of disputes in terms of project parties and phases of project. Thus, Table 2 clusters a total of twenty (20) significant causes identified in previous section under parties responsible and stages of construction project.

Table 2: Causes of Disputes - Perspective of Project Parties and Project Phases

<table>
<tr><th colspan="2"></th><th>Inception</th><th>Design</th><th>Tendering</th><th>Construction</th></tr>
<tr><td rowspan="2">Client</td><td>Unique</td><td></td><td></td><td></td><td>▪ Payment delays
▪ Unstable financial status of client</td></tr>
<tr><td>Common</td><td colspan="4">▪ Variation initiated by owner/scope changes
▪ Poor communication
▪ Unrealistic expectations/ time targets
▪ Negligence/lack of professionalism</td></tr>
<tr><td rowspan="3">Consultant</td><td>Unique</td><td>▪ Unclear and unfair risk allocation
▪ Inappropriate selection of procurement method
▪ Inadequate brief</td><td>▪ Design errors
▪ Inadequate/ incomplete specification and drawing</td><td>▪ Unclear and unfair risk allocation</td><td>▪ Payment delays due to delay in evaluation of completed works</td></tr>
<tr><td rowspan="2">Common</td><td></td><td></td><td colspan="2">▪ Ambiguities in contract document
▪ Different interpretation of contract provisions
▪ Unavailability of information</td></tr>
<tr><td colspan="4">▪ Poor communication
▪ Negligence/lack of professionalism</td></tr>
<tr><td rowspan="2">Contractor</td><td>Unique</td><td></td><td></td><td></td><td>▪ Variations/ scope changes
▪ Poor quality of work
▪ Poorly done planning and scheduling
▪ Inadequate contract administration
▪ In competent contractor</td></tr>
<tr><td>Common</td><td></td><td></td><td colspan="2">▪ Poor communication
▪ Negligence/lack of professionalism</td></tr>
<tr><td rowspan="2">External Factors</td><td>Unique</td><td></td><td></td><td></td><td>▪ Site conditions</td></tr>
<tr><td>Common</td><td colspan="4">▪ Legal and economic factors</td></tr>
</table>

This reveals that all three parties namely; contractor, client and consultant are contributing to disputes in different stages of the project. Some of the causes identified fall under external factors. Four major project stages such as inception, design, tendering and construction are considered in the classification. The causes; poor communication and negligence/ lack of professionalism are identified as responsible by all three parties throughout the construction project. The Table further portrays that consultant contributes more to disputes while client and contractor are responsible for less number of of the causes. The parties; consultant, contract and client are responsible for 11, 7 and 6 number of causes respectively.

As the consultant involves from the inception stage of project, the consultant contributes to disputes in various ways. For example, during the inception stage the consultant responsible for the causes of inadequate brief, unclear and unfair risk allocation, inappropriate selection of procurement method. During design stage, consultant is responsible for the causes of inadequate/ incomplete specification and drawing, unclear and unfair risk allocation, ambiguities in contract document, different interpretation of contract provisions and unavailability of information. The document such as drawing, specification, and tender document related problems occur due to consultant in tendering stage. In construction stage, consultant contributes to disputes due to payment delays due to delay in evaluation of completed works, inadequate/ incomplete specification and drawing, ambiguities in contract document, different interpretation of contract provisions and unavailability of information. Among those causes, according to the Table, payment delays considered as most significant contributory factor.

As per traditional arrangement, contractor involvement starts from the tendering stage. However, contractor causes to disputes during the construction phase in terms of variations/ scope changes, poor quality of work, poorly done planning and scheduling, inadequate contract administration, and in competent contractor. Out of these causes, poor quality of work is the 6th significant cause for dispute occurrence. Table 2 reveals that the client contributes less to disputes than contractor and consultant. Client contributes to disputes due to six (06) numbers of causes such as payment delays, unstable financial status of client, variation initiated by owner/scope changes, poor communication, unrealistic expectations/ time targets and negligence/lack of professionalism. Though the client less contributes to dispute in terms of number of causes, he is responsible for most of the top significant causes such as variation initiated by owner (1st) and payment delays (3rd).

In addition to parties to contract, the external factors also cause disputes in projects. The external factors include weather changes, site conditions, major accidents, environmental pollution, unexpected social event, bureaucratic/ delay in approvals, uncertainty, task interdependency, inflation and alike. Among these factors, site conditions and legal and economic factors marked as most significant causes of disputes.

3.3 CAUSES OF DISPUTES - PERSPECTIVE OF PROJECT CHARACTERISTICS

The ultimate goal of the project participants is successful delivery of project which is often influenced by the project characteristics (Cho, Hong, & Hyun, 2009). On this note, the researchers (Alhazmi and McCaffer, 2000; Love *et al*., 1998) sought to identify the project characteristics over the years. The authors found a range of project characteristics such as project type, project size, project cost, project duration, time constraints construction method, site factor, risk factor, usage of technology, degree of flexibility, degree of complexity, payment method, project funding method and procurement method.

Walker (1995) suggested that project scope as a useful predictor for project duration which is an indicator to measure the project success. On the other hand, many researchers indicated that the attributes used to measure project scope are type of project, nature of project, number of floors of the project, complexity of project, and size of project (Akinsola *et al*. 1997; Dissanayaka and Kumaraswamy 1999; Kumaraswamy and Chan 1999).

Chan, Scott, and Chan (2004) found that less complex projects with shorter duration and executed by private and experienced client who is competent on preparing brief and making decision are recorded as successful project. Further, Chan *et al*. (2004) added that the projects executed in a stable environment with developed technology together with an appropriate organization structure, and having a competent and experience team leader are also registered as success factors. Thus, Chan *et al*. (2004) confirmed that the project characteristics of degree of complexity, duration, project management, and technology are influencing in success of the project.

In contrast, Ojo (2012) found project characteristics as major causes of inaccurate cash flow prediction which makes it exposed to more risk, and the extent of its impact is a major concern to the construction disputes. On this note, Alhazmi and McCaffer, (2000) suggested that project characteristic should be considered in every stages of project.

In terms of complex projects, Motsa (2006) stated that the complex projects are likely to have more ramifications when a change is made. In addition, the author opined that complex projects require additional time for designing than usual projects. The time allocated for the designing of usual project is not enough for a complex project and therefore it requires number of addenda and creates frequent errors in projects. Thus, shorter period allocated for design may lead to disputes in construction projects.

In terms of size of the project, Hall (2002) suggested that large project involves a range of people, drawings, thoughts, and ideas. Consequently, larger project tends to experience more errors. In support of this, researchers identified that errors cause disputes in construction projects (Love *et al*., 2010; Cakmak and Cakmak, 2013; Kumaraswamy, 1997). Thus, Cakmak and Cakmak (2013) found that disputes occur due to design related errors in terms of design errors, incomplete specifications, poor quality design, unavailability of information, and ambiguity in documents.

On a different note, Ashworth (2006) suggested that large projects are subjected to time and cost overruns. According to Ren, Anumba, and Ugwu (2003), a contractor demands his entitlement by asking for extension of time and addition cost incurred when there are time and cost overruns. Once client disagree with contractor's claim, disputes arise in a construction project. On a similar note, many of the researchers indicated that cost and time overrun could lead to disputes, arbitration, and even total abandonment of project (Rahman *et al.*, 2008; Enshassi *et al*., 2008).

In terms of procurement method, the traditionally procured projects experience more disputes, while partnering and alliancing provide less prospects for disputes. Cheung (1999) suggests that the use of partnering and alliancing create team building and harmony, and thereby prevent disputes. Both partnering and alliancing emphasise on early association of key stakeholders including clients, contractors and consultants in decision making process.

The foregoing indicates that the disputes have potential to relate with project characteristics. Thus, Figure 1 summarises the findings on causes of disputes in terms of project characteristics.

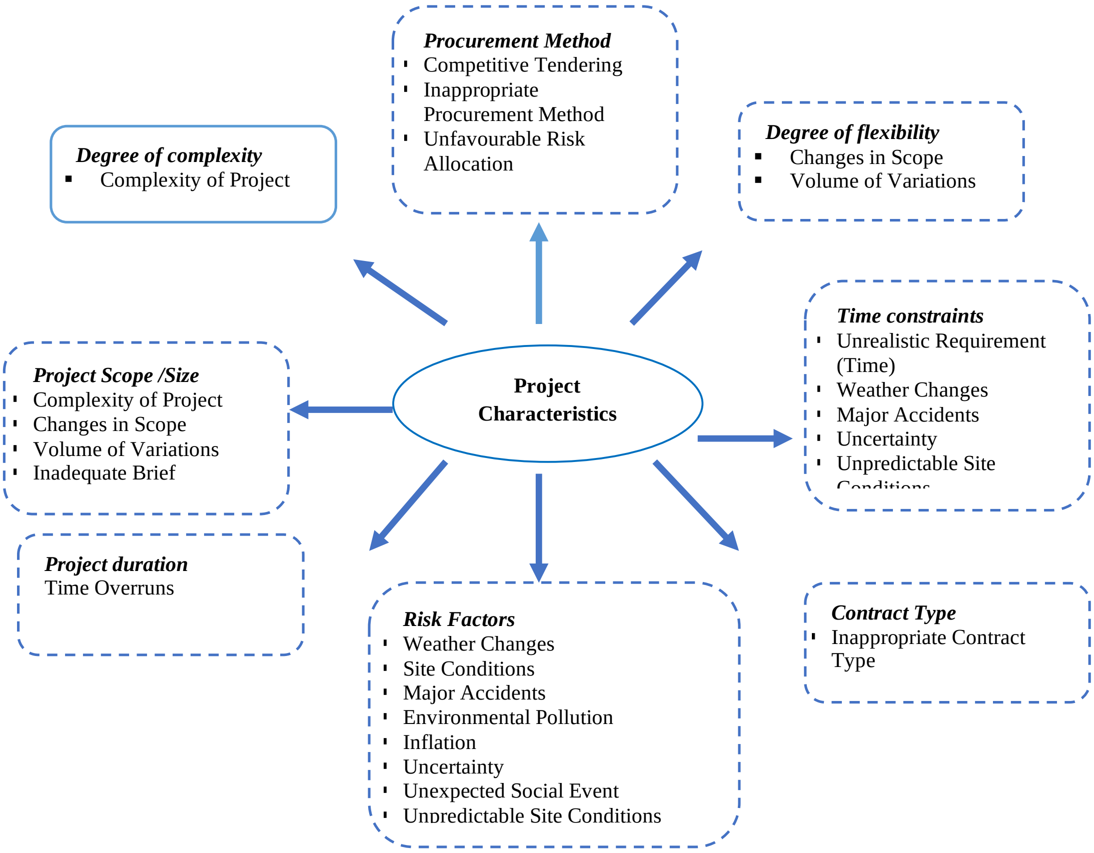

Figure 1: Causes of Disputes - Perspective of Project Characteristics

Figure 1 portrays the key project characteristics along with the possible causes. A total of twenty four (24) causes are identified under eight key project characteristics. Among those possible causes, a total of seven (07) are found to be significantly contributing to disputes as depicted in section 3.1. They are inappropriate procurement method, unfavourable risk allocation, changes in scope/variation, inadequate brief, site conditions legal and economic factors and unrealistic requirement (time). In addition, the causes of inappropriate procurement method, unfavourable risk allocation and inadequate brief occur during the early stages (inception stage) of a construction project as stipulated in Table 2. Thus, the review provides a way to consider management of disputes during the early stage of a construction project by addressing the significant causes with the focus of project characteristics and project parties.

4. CONCLUSIONS

Disputes are not uncommon in today's complex and competitive construction environment. Disputes are associated with distinct justifiable issues and require to be managed. Failure to address disputes result in minor issues to fester and grow, often with negative consequences for project participants. Such effects are in many folds starting from cost and time over run to abandonment of project. As an initial step to manage, this study identified the significant causes of disputes and investigated the causes with the focus of project participants, project phases and project characteristics.

A comprehensive literature review is carried out referring reliable publications in the area of disputes and the related issues in a systematic way. The research identified a total of fifty (50) causes of disputes through the initial review. Further, the review sorted 20 top significant causes of disputes. Among those, variation initiated by owner/scope changes, inadequate/incomplete specification and drawing and payment delays are identified as most significant causes of dispute with the frequency of 11 out of 15. Scope changes and payment delays occur due to client whereas consultant is responsible for inadequate/incomplete specification and drawing. Therefore, the research further investigated the causes in terms of project parties and project phases. Thus, the causes were again clustered under project parties and project phases. The classification revealed that the client, consultant, and contractors are responsible for a total of 6, 11 and 07 respectively. In addition, the research further found that the project characteristics have a relationship with causes of disputes. For example, the causes of inappropriate selection of procurement method and unfair risk allocation have been identified under the project characteristic, procurement method. Thus, the possible causes were categorised under key project characteristics. Finally, the research suggests industry practitioners belongs to each parties to seek for effective ways of managing disputes beforehand, with the view point of project characteristics from the early stage of construction project.

5. REFERENCES

Acharya, N.K., and Lee, Y.D., 2006. Conflicting factors in construction projects: Korean perspective. *Construction and Architectural Management*, 13(6), 543-566.

Akinsola, A. O., Potts, K. F., Ndekugri, I., and Harris, F. C. 1997. Identification and evaluation of factors influencing variations on building projects. *International Journal of Project Management*, 15(4), 263–267.

Alhazmi, T., and McCaffer, R., 2000. Project Procurement System Selection Model, *Journal of Construction Engineering and Management*,176-184.

Armes, M., 2011. *The concept of dispute avoidance. An Introduction to International Adjudication* (pp. 1-9). London: Kings College.

Ashworth, A., 2006. *Contractual procedures in the construction industry* (5th ed.). England: Person Education Ltd.

Cakmak, E., and Cakmak, P. I., 2013. An analysis of causes of disputes in the construction industry using analytical network process. *Social and Behavioral Sciences , 109* (2014), 183 – 187.

Carmichael, D.G., 2002, *Disputes and International projects*. Liase: A.A. Baklava Publishers

Chan, A. P., Scott, D., and Chan, A. P., 2004. Factors Affecting the Success of a Construction Project. *Journal of Construction Engineering and Management* , 130(1), 153-155.

Chan, E. H. W., and Suen, H. C. H., 2005. Dispute resolution management for international construction projects in China. *Management Decision*, 43(4), 589–602.

Cheung, S. O., 1999. Critical factors affecting the use of alternative dispute resolution processes in construction. *International Journal of Project Management* , 17 (3), 189–194.

Cheung, S. O., and Pang, H. Y., 2014. *Conceptualising Construction Disputes*. Switzerland: Springer International Publishing Switzerland.

Cheung, S., and Yiu, T., 2006. Are construction disputes inevitable? *IEE Transactions on Engineering Management , 53* (3), 456-470.

Cho, K., Hong, T., and Hyun, C., 2009. Effect of project characteristics on project performance in construction projects based on structural equation model. *Expert Systems with Applications* , 36 (2009), 10461–10470

Chong, H., and Zin, R. M., 2012. Selection of dispute resolution methods: Factor analysis approach. Engineering, *Construction and Architectural Management* , 19 (4), 428–443.

Colin, J., Langford, D., and Kennedy, P., 1996. The relationship between construction procurement strategies and construction contract conflicts. *In Proceedings of the CIB W-92 Procurement Symposium.* 14th & 16th January, Durban, South: North Meets West.

Dissanayaka, S. M., and Kumaraswamy, M. M. 1999. ‘‘Evaluation of factors affecting time and cost performance in Hong Kong building projects.’’ Engineering Construction Architectural Management., 6(3), 287–298.

Enshassi, A., Mohammed, S., and Mosa, J. A., 2008. Risk management in building projects: contractors’ perspective. *Emirates Journal for Engineering Research*, 13(1), 29-44.

Farooqui, R. U., and Azhar, S., 2014. Key Causes of Disputes in the Pakistani Construction Industry– Assessment of Trends from the Viewpoint of Contractors. In: *50th ASC Annual International Conference Proceedings.* Pakistan: Associated Schools of Construction.

Fink A., 1998. *Conducting research literature reviews: from paper to the internet.* Thousand Oaks: Sage.

Hall, J. M., 2002. *Ineffective communication: Common Causes of Construction Disputes Alliance"s Advisory Council Legal Notes.* 13(2).

Harland, C. M, Lamming, R.C, Walker H, Philips W.E, Caldwell N.D, and Johnson, T.E, 2006. Supply management: Is it a discipline? *International Journal of Operations & Production Management,*26(7):730–53.

Kassab, M., Hegazy, T., & Hipel, K. (2010). Computerised DSS for construction conflict resolution under uncertainty. *Journal of Construction Engineering and Management , 136* (12), 1249-1257.

Khahro, S. H., and Hussain Ali, T., 2014. Causes leading to conflicts in construction projects: A viewpoint of Pakistan Construction Industry. In: *International Conference on challenges in IT, Engineering and Technology*, (pp. 116-121). 17th & 18th July 2014, Phuket, Thailand.

Kumaraswamy, M. M., 1997. Conflicts, claims and disputes in construction. *Engineering, Construction and Architectural Management , 4* (2), 95 – 111. 19

Kumaraswamy, M. M., and Chan, D. W. M. 1999. Factors facilitating faster construction. *Journal of Construction Procurement*., 5(2), 88–98.

Love, P. E., Davis, P., London, K., and Jasper, T., 2008. Causal modelling of construction disputes. In: *twenty-fourth annual Association of Researchers in Construction Management conference* (pp. 869–878). 1st-3rd September 2008, England: ARCOM.

Love, P., Davis, P., Ellis, J., and Cheung, S. O., 2010. Dispute causation: identification of pathogenic influences in construction", *Engineering, Construction and Architectural Management*., 17 (4), 404-423.

Love, P., Skitmore, M., & Earl, G., 1998. Selecting a suitable procurement method for a building project. *Construction Management and Economics*, 16(2), 221-233.

Love, P.E.D., Edwards, D., and Smith, J., 2006. Contract documentation quality and rework in Australian projects. *Journal of Architectural Engineering and Design Management*, 1(4), 247-259.

Mitropoulos, P., and Howell , G. A., 2001. Model for understanding, preventing, and resolving project disputes. *Journal of construction engineering and management*, 127(3), 223-231.

Motsa, C.D., 2006. *Managing construction disputes*, Thesis (Master). Universiti Teknologi Malaysia.

Na Ayudhya, B. I., 2011. Common disputes related to public work projects in Thailand. *Journal of Science and Technology , 33* (5), 565-573.

Odeh, A.M and Battaineh, H. 2002. Causes of construction delay: Traditioanl contracts, *Interanatioanl Jouranal of Project Management.* 20(1), 67-73.

Ojo, G. K., 2012. Project characteristics influence on risk associated with construction clients’ cash flow prediction. *Journal of Research in International Business and Management* , 2 (5), 142-150.

Rahman, H. A., Yahya, I., Berawi, A., and Wah, L. 2008. Conceptual delay mitigation model using a project learning approach in practice. *Construction Management and Economics*, 26(1), 15-24.

Ren, Z., Anumba, C., and Ugwu, O. 2003. Multiagent system for construction claims negotiation. *Journal of Computing in Civil Engineering*, 17(3), 180-188

Sheridan, P., 2003. Claims and disputes in construction. *Construction Law Journal*, 12(1), 3–13.

Sinha, M., and Wayal, A. S., 2013, Dispute Causation in Construction Projects. *Journal of Mechanical and Civil Engineering*, 13(1), 54-58.

Steen, R.H., 2002. Alternative Dispute Resolution in the Construction Industry.[Online]. Available from: http://eprints.utm.my/36564/3/IntanBayaniZakariaMFAB2010CHAP1.pdf, [Accessed 15 Aug 2016].

Thobakgale, M. E., Aigbavboa, C. O., and Thwala, W. D., 2014. Professional's Perception on the Causes and Effects of Disputes in the Construction Industry – A Theoretical Exploration. In: *6th International Conference on Humanities, Geography and Economics*, (pp. 135-137). Cape Town, South Africa.

Waldron, B.D., 2006. *Scope for improvement: A survey of pressure points in Australian Construction and Infrastructure Projects.* Blake Dawson Waldron, Sydney.

Walker, D. H. T., 1995. An investigation into construction time performance. *Construction Management and Enonomics*, 13(3), 263–274.

Yiu, K.T.W and Cheung, S.O., 2007, Behavioural transition: A framework for construction conflict-tension relationship, *IEEE Trnasactions on Engineering Management*, 54(3), 498-505.

Zaghoul, R., and Hartman, F., 2003. Construction contracts: The cost of mistrust. *International Journal of Project Management* , 21(6), 419-424.

RISK MANAGEMENT OF GREEN RETROFITTING PROJECTS IN SRI LANKA

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ABSTRACT

The comparison made upon other developed and developing countries proves that green retrofitting projects are entirely new to the Sri Lankan construction industry. Green retrofit can be defined as an upgrade, extension and alternation, change the use of building, renovation of existing buildings. In such, partially or wholly occupied existing buildings are upgraded by integrating sustainable or green features to achieve its foremost benefits. However, green retrofitting of existing buildings are riskier than constructing a new building as where it requires a proper strategy to manage the risk. Hence, evaluating the risk in green retrofit projects is very helpful to construction industry as it may assist to get right decision about the project and also to well handle and manage it. Thus, this research aims to propose probable risk responsive strategies through a comprehensive risk assessment of green retrofitting projects in Sri Lanka.

As the first step in research process, thirty risk factors were identified by reviewing key literature relating to five major categories, such as, financial, market, industry, performance and legislative risks. The identified factors are evaluated through questionnaire survey which was conducted among forty experienced green professionals in three selected green retrofitting projects in Sri Lanka. The survey data are analysed based on its criticality by using descriptive statistical analysis techniques to identify high, moderate and low risk factors. According to overall results, ten risk factors are determined as 'critical' factors, such as, construction cost, inflation, energy saving uncertainty, warranty risk, delay in project completion, requirement of permits and their approval, design changes, procurement delay, damage to structure or property etc. Finally, risk responsive strategies are proposed to avoid, reduce, retain and/or transfer the identified risks of green retrofit projects as the final outcome of this research. Further, this research implies a way of ensuring an effective risk management of green retrofit projects in Sri Lanka and other developing countries.

Keywords: *Green Retrofitting; Risk Assessment; Risk Responsive Strategies; Sri Lanka.*

1. INTRODUCTION

The governing concern of today’s world is to reduce the effect of greenhouse gas emission and its contribution towards global climatic challenges. As the third responsible party who increase greenhouse gas emission in the world, buildings and construction industry are looking towards a new era with modern and environmentally friendly building approaches. Bu *et al*. (2015) mentioned that today most of the organizations tend to convert their existing building into green due to its foremost benefits. Therefore, many organizations get their maximum effort to achieve energy efficiency through green retrofitting.

As explained by Al-Kodmany (2014), green retrofitting is a “any kind of upgrade at an existing building that is wholly or partially occupied to improve energy and environmental performance, reduce water use, and improve the comfort and quality of the space in terms of natural light, air quality, and noise; all done in a way that it is financially beneficial to the owner”. Therefore, retrofitting of existing building into green building represents a major part of the construction industry. Now Sri Lanka has started to increase the development projects with green retrofitting. Green Building Council of Sri Lanka appeared as a consequence of a

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developing pattern towards applying the greener ideas for manufactured environment (Green Building Council of Sri Lanka - GBCSL, 2015).

As Baek and Park (2012) mentioned, green retrofitting of an existing building can be a high risky process than constructing a new building. Eichholtz *et al*. (2010) further stated that green retrofitting of existing buildings can be associated with many challenges and risk factors, such as, climate changes, service changes, policy and regulation changes and human behavioral changes etc. Even though, various factors may influence green retrofitting, most of the occupants have identified that green retrofit building could achieve productivity through energy saving and therefore current demands for the green retrofitting existing building has increased. Thus, risk assessment is essential to identify probable responsive strategies for risk factors associated to green retrofit projects. Further, having an effective risk management plan for green retrofitting projects is also essential to achieve its foremost benefits, to get correct decisions on project investments and to well handle the risk events in retrofitting projects invested (Menassa, 2011). In response to above concerns, evaluating the risk associated to green retrofitting projects in Sri Lanka is more appropriate and it will be more worthwhile to establish an effective risk management plan for increasing future investments on green retrofitting.

2. LITERATURE REVIEW

2.1. RISK MANAGEMENT FOR GREEN RETROFITTING PROJECTS

Green Retrofit is a building system renovating process and how creates structure of a building to improve energy efficiency, resource consumption decrease in the building, and create indoor air quality in good condition (Roper and Pope, 2014). Douglas (2006) also defined that "Green retrofit is an adaption of existing building to the new condition through changing maintenance activities, changing functions and performance of the building". Moreover, Ma *et al*. (2012) explained that green retrofit creates environmental responsible, efficient resource structures and process for building life cycle. As a developing country, Sri Lanka shows a movement over various foundation improvements which joined by some measure of environmental prolapsed and expanded carbon emission (Dissanayake, 2015). As the green building concept is entirely new to Sri Lankan construction industry, it is quickly extending all over various enterprises while scanning for more vitality effective structures for their use. Sri Lanka has started to change the development business with green retrofitting projects.

There are many kind of risks associated with green retrofitting projects, including common risk of construction project because green retrofitting is a risky process as where it requires proper strategy to manage the risk for achieving its foremost benefits. Risk management is the identification, assessment, and prioritization of risks. Risk management process refers approach, so that timely mitigation actions are initiated to avoid risk, transfer risk, reduce risk likelihood or reduce risk impact (Ahamed *et al*., 2007). Risk management is a systematic approach to minimizing an organizations exposure to risk. Risk management system includes various policies, procedures and practices that work in unison to identify, analyze, evaluate, address and monitor risk (Finch, 2004). The systematic risk management in any project has long been recognized as an effective approach to minimizing risk impacts.

2.2. RISK FACTORS ASSOCIATED TO GREEN RETROFITTING PROJECTS

Most of the construction projects are associated with risks. Green retrofitting projects generate more benefits to the environment, occupants and the economics hence there are risks associated with the project. In Sri Lanka many organizations need their building structures to be "green" and they face set of risk exposures. As a developing nation, Sri Lanka move towards existing building green retrofitting idea to reduce environmental effect. Compared to other construction projects there are numerous risk factors connected with the green retrofit projects, in Sri Lanka. The combination of risk such as, financial, legal and industry risk are affected to the most of the green projects (Mallikage, 2015). Further, risk management process contributes to reduce energy consumption and management cost.

These risks can be divided in to five categories such as financial risks, market risks, industry risks, performance risks, legislative risks (Eichholtz *et al*., 2010). There are thirty (30) risk factors were identified relating to above risk categories by reviewing key literature (Davidson *et al*., 2012; Drew, 2011; Chanter and Swallow, 2007; Drew, 2011; Miller and Buys, 2008).

Table 1 presents the key risk factors associated to green retrofitting of existing buildings.

Table 1: Risk Factors Associated to Green Retrofitting

Risk factor	Sub factors
Financial risk	Inappropriate financial model Inadequate return investment and payback Higher cost than anticipated operating expenses Inflation
Market risk	Unable to achieve expected value Not meeting benefits of the green building Reliability and accuracy bench mark lack of consensus in the market
Industry risk	Man-power supply and availability risk Material supply availability risk New and untested product and material Lack of experience of consultant and subcontractor
Performance risk	Failure to meet green code or green certification Energy saving uncertainty Warranty risk Delay in project completion Accreditation of energy saving companies Team performance risk Indoor air quality issues Productivity and quality risks Pre-retrofit tenant cooperation risk Post retrofit tenant cooperation risk Lack of knowledge regarding structure
Legislative risk	Tax changes Regulatory incentives changes Change of green building codes and mandate Requirement of permits and their approval

According to key literature reviewed, financial risk category includes, inappropriate financial model inadequate return investment and payback, higher cost than anticipated operating expenses, inflation and loan interest while, unable to achieve expected value, no meet client expectation, productivity risk and new compliance requirement are identified as market risk factors. Man power supply and availability risk, material supply availability risk, new and untested product and material, lack of experience of consultant and subcontractor are the industry risk factors reviewed. Failure to meet green code or green certification, energy saving uncertainty, warranty risk, accreditation of energy saving companies, team performance risk, indoor air quality issues, reliability and accuracy bench mark, quality risks, pre retrofit tenant cooperation risk, post retrofit tenant cooperation risk and lack of knowledge regarding structure are identified as performance risk factors while legislative risk category includes four key factors such as tax changes, regulatory incentives changes, change of green building codes and mandate and requirement of permits and their approval.

3. RESEARCH METHODOLOGY

Qualitative and quantitative research approaches are the two main approaches of research design. As this research aimed to conduct a risk assessment for green retrofit projects in Sri Lanka, quantitative research approach was selected. It was further justified by several other facts, such as, investigating significant risk factors and developing a risk matrix by using impact and probability calculation. Further, it involves collecting data from a fraction of population and generalizing the findings to the population with quantitative descriptions. Therefore, considering all factors quantitative research approach was executed in the research.

As a systematic method of collecting data based on a literature review, the questionnaire survey technique was used to collect professional views on green retrofitting. Before having a questionnaire survey, a preliminary survey was carried out in order to understand the risk factors affecting to the green retrofit projects. It was focused to identify green retrofitting projects in Sri Lankan Context and, risk factors associated with them. Accordingly, three additional factors are added to the profile of risk factors such as loan interest, delay in project completion and construction cost.

For the main survey, forty (40) respondents consisting the professionals of green retrofit projects namely architects, engineers and managers including project managers and maintenance managers who had experience above three years in the field of green buildings were randomly selected from green retrofit projects in Sri Lanka. From the respondents to whom that the detailed questionnaire was distributed, 32 were returned by maintaining the 80% of response rate.

As the choice of multiple data collection techniques over single method generates benefits to research, both questionnaire and semi-structured interview techniques were used in this research. As this research focused on quantitative phenomenon, questionnaire survey was selected as primary data collection technique. Five semi-structured interviews were conducted among selected respondents in the main survey to validate the results and to propose probable risk responsive strategies. The survey data was analysed by using descriptive statistics. Mode value of each factor was used for risk assessment. The respondents were asked to rank each risk factor, according to 1-5 scale for impact and probability of each risk. The mode value of each risk factor is counted for subsequent analysis.

According to the Elmontsri (2014), risk matrix can be used to rank risk factors by using 4x4 or 5x5 matrices having event consequences along the other axis. Thus, in this research, the risk rating matrix was used to characterize and rank the identified risk factors.

The findings derived in risk assessment are described subsequently.

4. RESEARCH FINDINGS AND DISCUSSION

The analysis and key findings are derived in two sub sections, namely, risk evaluation and risk rating matrix of green retrofitting projects in Sri Lanka.

4.1. RISK EVALUATION

In risk evaluation, the risks associated to green retrofit projects are evaluated in related to the risk categories of financial, market, industry, performance and legislative risk. The probability and impact of each risk factor are calculated by using mode value in statistical data analysis. The risk score for each factor was determined based on 'severity of its impact' as shown in Table 2.

Table 2: Probability and Impact of Risk Factors

Category	Risk factor		Probability	Impact	Risk score
Financial Risk	RF1	Construction cost	3	4	12
	RF2	Inappropriate financial model	1	4	4
	RF3	Inadequate return investment and payback	3	3	9
	RF4	Higher cost than anticipated operating expenses	2	4	8
	RF5	Inflation	4	4	16
	RF6	Loan interest	1	2	2
Market Risk	RF7	Unable to achieve expected value	2	2	4
	RF8	No meet client expectation	1	3	3
	RF9	Productivity risk	1	3	3
	RF10	New compliance requirement	3	3	9
Industry Risk	RF11	Man power supply and availability risk	2	2	4
	RF12	Material supply availability risk	2	3	6

Performance Risk	RF13	New and untested product and material	3	3	9
	RF14	Lack of experience of consultant and subcontractor	1	3	3
	RF15	Failure to meet green code or green certification	1	3	3
	RF16	Energy saving uncertainty	4	5	20
	RF17	Warranty risk	4	3	12
	RF18	Delay in project completion	2	5	10
	RF19	Accreditation of energy saving companies	2	2	4
	RF20	Team performance risk	3	3	9
	RF21	Indoor air quality issues	2	2	4
	RF22	Reliability and accuracy bench mark	1	3	3
	RF23	Quality risks	4	4	16
	RF24	Pre retrofit tenant cooperation risk	3	1	3
	RF25	Post retrofit tenant cooperation risk	3	3	9
	RF26	Lack of knowledge regarding structure	3	2	6
Legislative Risk	RF27	Tax changes	1	2	2
	RF28	Regulatory incentives changes	1	2	2
	RF29	Change of green building codes and mandate	2	3	6
	RF30	Requirement of permits and their approval	3	5	15
Other	RF31	Design changes	4	5	20
	RF32	Procurement delay	4	4	16
	RF33	Damage to structure or property	3	5	15
	RF34	Delay payments on contract	3	3	9
	RF35	Design errors	3	3	9

According to the statistical analysis, inflation showed high probability (mode = 4) and impact (mode = 4) among the other factors where inappropriate financial model and loan interest showed low probability and impact to green retrofitting. In the market risk category, new compliance requirement showed high probability (mode = 3) and impact (mode = 3) whilst new and untested product and material was the one which received high risk score in the industrial risk category (probability = 3; impact = 3).

Among the performance risk factors, energy saving uncertainty, quality risk, delay in project completion and warranty risk showed respectively high probability and impact on green retrofitting. The requirement of permits and their approval in the legislative risk category is other significant factor, which showed high probability (mode = 3) and impact (mode = 5) values. As the other factors identified, design changes, procurement delay and damage to structure and property are identified as another significant risk factors which showed high probability and impact on green retrofitting as shown in Table 2.

4.2. RISK RATING MATRIX OF GREEN RETROFITTING PROJECTS IN SRI LANKA

The common score calculated for each risk factor is used to assign relevant values in risk matrix by multiplying the impact and probability. The overall risk matrix is developed for green retrofitting projects is presented in Figure 1.

All the resulted were presented to determine a common score for risk factor.

Risk score = Probability × Impact

Probability of Occurrences		Severity of Impacts				
		Low	Minor	Moderate	Significant	Severe
Definition	Value	1	2	3	4	5
Probable	1		RF6, RF27, RF,28	RF22, RF 24		
Seldom	2		RF7, RF21	RF26, RF29		
Occasional	3	RF8, RF9, RF15	RF11, RF12, RF21	RF3, RF10, RF13, RF20, RF25, RF34, RF35	RF1	RF33
Likely	4	RF2, RF19	RF4	RF17	RF5, RF23, Rf32	
Frequent	5	RF5, RF14	RF18	RF30	RF16, RF31	

Figure 1: Risk Rating Matrix of Green Retrofitting Projects in Sri Lanka

Accordingly, the low, medium, high and extreme risk factors are determined based on the risk rating matrix.

Table 3: Risk Score and Related Risk Ratings

Risk Score	Risk Rating	Risk Factors
1-4	Low Risk	RF22, RF24, RF6, RF27, RF28, RF7, RF21, RF8, RF9, RF15, RF2, RF19
5-9	Medium Risk	RF26, RF29, RF11, RF12, RF21, RF4, RF5, RF14, RF3, RF10, RF13, RF20, RF25, RF34, RF35
10-16	High Risk	RF17, RF18, RF30, RF1, RF33
16-25	Extreme Risk	RF5, RF23, RF32, RF16, RF31

According to overall results shown in Table 3, ten (10) risk factors were determined as critical risk factors which are included in high (brown) and extreme (Red) risk levels of risk matrix. Under performance risk and other category, energy saving uncertainty and design changes became most critical risk factors in green retrofitting projects. As per the severity of risk factors, the risk responsive strategies are determined accordingly.

4.3. PROPOSED STRATEGIES

Based on the ideas gathered through literature and semi-structured interviews conducted, the risk responsive strategies are proposed to mitigate low, medium high and extreme risks of green retrofitting project in Sri Lanka by relating to four risk responsive strategies which are available for dealing with risks, such as, avoid, retain, reduce and transfer (refer Table 4).

Table 4: Risk Responsive Strategies Proposed

Category	Risk Factor	Risk Rating	Risk Response	Proposed Strategies
Financial Risk	Construction cost	High risk	Transfer	Re structuring the financial cost Use the expertise team to the project Adopting green strategies and including them in the budget from an early stage
	Inappropriate financial model	Low risk	Retention	Retrofit in stage
	Inadequate return investment and payback	Medium risk	Reduction	Document building performance Proper plan on which area to be concern for LEED accreditation

	Higher cost than anticipated operating expenses	Medium risk	Reduction	Follow project life cycle as planed Conduct progress meeting with all supported staff
	Inflation	Extreme risk	Avoid/Transfer	Accept the risk
	Loan interest	Low risk	Retention	Keep Relationship with bank
Market Risk	Unable to achieve expected value	Low risk	Retain/Reduction	Use Geographic Information Systems to analyse the market Aware all team members to explore market
	No meet client expectation	Low risk	Retain/Reduction	Aware about all client and their expectation
	Productivity risk	Low risk	Retain/Reduction	Create new performance schedule Plan to maximize productivity Improve work environment
	New compliance requirement	Medium risk	Reduction	Documenting performance and savings data
Industry Risk	Man power supply and availability risk	Medium risk	Reduction	Develop machinery and automation usage Get the service of a qualified and licensed contractor
	Material supply availability risk	Medium risk	Reduction	Schedule material supply carefully Industry institutions and government to provide a portal or list of green materials available Get government support to invest and develop in green material and the researches Get materials from approved suppliers
	New and untested product and material	Medium risk	Reduction	Preparing database for green materials Use modern technologies to collect timely data Use tested green materials
	Lack of experience of consultant and subcontractor	Medium risk	Reduction	Hire experienced consultant and sub-contractors based on history rewards/profiles Establish educational programs for industry professionals Retain experienced and knowledgeable team members
Performance Risk	Failure to meet green code or green certification	Low risk	Retention/ Reduction	Get the services from experience and green -consultant Change the structure or material to overcome identified problems
	Energy saving uncertainty	Extreme risk	Avoid	Establish a performance based contract with the consultants Proper energy simulation Insurance cover and
	Warranty risk	High risk	Transfer/ Reduction	Purchase insurance Material quality test
	Delay in project completion	High risk	Transfer/Avoid	Using MS project create project schedule Motivate the project members Proper time management Daily meeting with contractors

	Accreditation of energy saving companies	Low risk	Retention/ Reduction	Check Energy Saving companies' credibility with reference to the list of ESCOs provided by the government
	Team performance risk	Medium risk	Reduction	Improve team members communication and integration Select the Design and Build delivery method Provide proper leadership to the project Allocate daily target to project team
	Indoor air quality issues	Low risk	Retention/ Reduction	Establish proper evaluation criteria Proper designing and commissioning
	Reliability and accuracy bench mark	Low risk	Retention/ Reduction	Prepare a “knowledge portal” for historical data
	Quality risks	Extreme risk	Avoid	Use tested and certified green materials Conduct routine checks to ensure the desired level of workmanship are met
	Pre retrofit tenant cooperation risk	Low risk	Retention/ Reduction	Perform retrofit work outside standard working hours Arrange relocation for the tenants Explain the rationale for retrofitting existing building to green building
	Post retrofit tenant cooperation risk	Medium risk	Reduction	Increase awareness of the benefits of retrofitting existing building to green building Provide incentives and rebates to the tenant
	Lack of knowledge regarding structure	Medium risk	Reduction	Provide knowledge regarding to the existing structure Contractor awareness
Legislative Risk	Tax changes	Low risk	Retention	Accept the risk
	Regulatory incentives changes	Low risk	Retention/ Reduction	Tap on government and financial incentives
	Change of green building codes and mandate	Medium risk	Reduction	Accept the risk Comply with mandates and codes
	Requirement of permits and their approval	High risk	Transfer/A void	Obtain legal advice Institution aspect properly address in project preparation Better coordination among stakeholders and various implementing agencies
Other	Design changes	Extreme risk	Avoid/Tran sfer	Insurance cover Adhere to proper design norms
	Procurement delay	Extreme risk	Avoid	Ensure assurance and completeness of documentation Prepare a realistic procurement plan
	Damage to structure or property	High risk	Avoid/Tran sfer	Physical protection to reduce risk Transfer risk to insurance company
	Delay payments on contract	Medium risk	Reduction	Prepare a proper financial plan
	Design errors	Medium risk	Reduction	Adhere to construction practice Use experienced architects and engineers

In green retrofit project, it has been noticed that the project consists of extreme, high, medium and low risks. Finally, based upon the level of each risk, proper risk response strategies were suggested together with their responsible parties. Prior identification of green retrofitting risks contributes to reduce its impacts to a greater extent by taking appropriate risk response strategies. Moreover, the project managers, architects and engineers on the respective green retrofit projects should be made responsible for managing project risks associated with that particular project and the project team members have to be assigned to specific areas of responsibility for reporting to the project manager. This may ensure the proper identification of risks throughout the project and thereby ensures the success of the project to a greater extent.

By enhancing the value of this research, following implications are highlighted as major outcomes derived from this research.

- The research outcome can use as a guideline for green retrofitting of existing building projects in Sri Lanka.
- Green retrofitting project team can carry out awareness programs to ensure project success and introduces risk response strategies would help to overcome risks and improve performance achievement of the project.
- Having a proper plan for managing risks in green retrofitting project could reduce the cost of the project and achieve the continuous improvement of the project process.
- Implementing green retrofitting of existing building can have to face various risks than new constructions. Therefore, the findings may help to allocate sufficient budget, provide proper communication and allocate responsibility for managing risks in green retrofit projects.

5. SUMMARY

The aim of this research was to propose probable risk responsive strategies through a comprehensive risk assessment of green retrofitting projects in Sri Lanka. The thirty (30) risk factors which were identified by reviewing key literature are evaluated by using descriptive statistical techniques; calculating the "Mode" value. The risk score for each factor was determined based on risk rating matrix. The low, medium, high and extreme risk factors are determined based on the overall risk rating matrix developed where, ten factor were determined as critical factors, such as, construction cost, inflation, energy saving uncertainty, warranty risk, delay in project completion, quality risks, requirement of permits and their approval, design changes, procurement delay, and damage to structure or property. Accordingly, probable risk responsive strategies are proposed as those factors could negative affect the project life cycle, financial status and performance issues of green retrofit projects in Sri Lanka.

6. REFERENCES

Ahamed, A., Kaysis, B. and Amornsawadwatana, S. (2007). A review of techniques for risk management in projects. *Benchmarking: an International Journal*, 14(1), 22-36.

Al-Kodmany, K. (2014). Green Retrofitting Skyscrapers: A Review. *Buildings*, 4(4), 683-710.

Baek, C.-H., and Park, S.-H. (2012). Changes in renovation policies in the era of sustainability. *Energy and Buildings*, 47, 485-496.

Bu, S., Shen, G., Anumba, C., Liang, X., and Wong, A.A. (2015). Literature review of green retrofit design for commercial buildings with BIM. *Smart and Sustainable Built Environment*, 4(2), 188 - 214.

Chanter, B., and Swallow, P. (2007). *Building maintenance management*. Oxford: Blackwell.

Davidson, K.M., Kellett, J., Wilson, L., and Pullen, S. (2012). Assessing urban sustainability from a social democratic perspective: a thematic approach. *Local Environment*, 17(1), 57-73.

Dissanayake, R. (2015). *Green buildings for sustainable built Environment in Sri Lanka Greensl? Or leed. Srilanka*: The Newspaper of the Institution of Engineers.

Douglas, J. (2006). *Building adaptation. Amsterdam*: Butterworth-Heinemann, Oxford.

Drew, L. (2011). *Careers in Green Construction*. Available from: http://www.bls .gov/green/construction [Accessed 22 June 2016]

Eichholtz, P., Kok, N.and Quigley, J.M. (2010). Doing Well by Doing Good? Green Office Buildings. American *Economic Review*, 100(5), 2492-2509.

Elmontsri, M. (2014). Review of the strengths and weaknesses of risk matrices. *Journal of Risk Analysis and Crisis Response*, 4(1), 49-57.

Finch, (2004), Supply chain risk management, *Supply Chain Management: An International Journal*, 9 (2), 183– 196.

Ma, Z., Cooper, P., Daly, D., and Ledo, L. (2012). Existing building retrofits: Methodology and state-of-the-art. *Energy and Buildings*, 55, 889–902.

Mallikage, S.T. (2015, April 02). *Green Building Concept and its Sri Lankan Context*. [online]. Forestry and Environment Science Blog. Available from: http://www.sjp.ac.lk/sites/forestry/2015/04/02/green-building-concept-and-its-sri-lankan-context [Accessed 22 January 2017]

Menassa, C.C. (2011). Evaluating sustainable retrofits in existing buildings under uncertainty. *Energy and Buildings*, 43(12), 3576-3583.

Miller, E., and Buys, L. (2008). Retrofitting commercial office buildings for sustainability: tenants' perspectives. Journal of Property Investment and Finance, 26(6), 552-561.

Roper, K.O. and Pope, B. (2014). Creating a framework for the successful implementation of energy retrofit projects. *Journal of Facilities Management*, 12(1), 38-35.

SIGNIFICANT FACTORS AFFECTING EFFECTIVENESS OF COMMUNITY-BASED ORGANISATIONS IN RURAL WATER SUPPLY SECTOR OF SRI LANKA

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ABSTRACT

Water as a basic need of all humans, their ultimate expectation is to have health and well-being life fulfilled with social and economic development through getting access to use of safe drinking water. Subsequently, providing adequate drinking water to all poor living areas has become a major challenge in developing countries like Sri Lanka. Community engagement in rural water supply (RWS) projects should become essential as the client and end-users are not involved in the project management process during a typical project. Therefore, the aim of the research is to investigate the factors which are significantly affect for effectiveness of Community Based Organisation (CBO) management in both client's perspective and community perspective.

A mixed approach was utilized for the study. A comprehensive literature review was intended to explore factors which are affecting for effectiveness of CBO management. Significant factors were observed through semi structured interviews based on Delphi technique to collect data on client's perspective. Questionnaire survey was carried out based on close ended questionnaires to collect CBO perspective data. Data was analysed via content analysis to generate qualitative outcome while RII technique was utilised to analyse statistical data.

Effective revenue, effective billing to collection ratio, effective CBOs' managerial level, effective stakeholder relationship and monitoring quality of water were identified as both perspectives agreed factors. The most significant factor on CBO perspective was considered as effective CBOs' managerial level while client perspective factors such as effective CBO involvement in operation and maintenance phase, development of CBO performance and relationship between National Water Supply and Drainage Board (NWS&DB) and CBOs was considered as most significant. Outcome of the study can be recommended to use as a tool before commencing the water supply project for aware about which factors are mostly assist to increase the effectiveness of CBO management.

Keywords: *Community Based Organisation; Rural Water Supply; Significant Factors.*

1. INTRODUCTION

Vagrants in rural areas are focusing on rural water supply (RWS), sanitation, and hygiene while achieving Millennium Development Goals (MDGs) (World Bank, 2004). Among such needs, providing adequate drinking water to such rural areas has become a major challenge in developing countries (Bethany and Deaton, 2015). Meanwhile, many challenges are met by Sri Lanka due to being a developing country in the course of achieving environmentally sustainable economic development for giving greater equity and opportunity to all its population (Teare *et al.*, 2013), while environmentally sustainable economic development means simultaneous reinforcement of environmental conservation and economic development goals. Community Based Organisations (CBOs) represent the community to deliver service at the local level from contributing labour, material and financial support to attain the aim of social services (Salles and Geyer, 2006). However,

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backstopping agency in developing countries, who is an external partner to the CBO, should encourage the community by giving suitable advice on effective project implementation to achieve good and high quality outcome (Ademiluyi and Odugbesan, 2008). Further Gbadegesin and Olorunfemi (2011) stated that it is still pending to find exact solution on getting maximum of CBOs involvement in construction stage of the project. Therefore, the study focused to investigate significant factors for the effectiveness of community based organisation (CBO) management in both client's perspective and community perspective during the lifecycle of rural water supply projects.

2. COMMUNITY MANAGEMENT APPROACH IN RURAL WATER SUPPLY SECTOR

Community management consists for serving humans while representing the responsibility of the government' or the donor agency (Bolt and Fonseca, 2001). Community management approaches were begun from a long history of trial and error in the RWS sector (Schouten and Moriarty, 2003). Further, stipulate that the history of concept of RWS had really started in the early 1960s. Yalegama *et al.* (2016) stated that the community based development approach is most suitable to developing countries such as Sri Lanka since this provides higher community engagement and measurable project management outcomes.

Community Management approach did not develop spontaneously from Water Decade (Schouten and Moriarty, 2003). This approach depends on the strengths of user communities and therefore it focused on getting the communities involvement in the management of RWS facilities (Rob *et al.*, 2016). Moreover, the capacities and willingness of the community was strengthened to take the ownership and responsibility of managing their water supply systems once the implementing agency leave the community (Schouten and Moriarty, 2003). Furthermore, community based development concludes that the community participation is an essential phenomenon and a very fundamental factor in RWS in Sri Lanka (Batuwitage, 2014).

The level of community involvement in RWS sector is changed by policy makers to suit the donors' requirements and also from the lessons learned from field experiences (Nwankwoala, 2011). Before 1977, the majority of the people living in the poor countries did not have proper and protected water and sanitation facilities (International Resource Centre [IRC], 2001). However, the community themselves constructed small scale water supply schemes like common wells and small piped systems before the international recognition (IRC, 2001). Brikke (2000) explained that, in early 1980s there were three main drivers to community participation-based approaches.

1. A new model for the development should come from the origins of a society rather than from the top.
2. There should be abroad awareness, because many traditional water supply policies and programmes were failing to achieve their goals.
3. Vision of the community participation concept could find a solution to the loss of the state's implementation capacity.

According to Brikke (2000), above mentioned factors should essential for existence of the community based organisations.

2.1. REQUIREMENT OF EFFECTIVE MANAGEMENT OF CBOS

Effectiveness is goal of increasing total output whereas efficiency consists of increasing output per unit (Laycock *et al*., 2009). Further, World Bank (2004) stipulated that increasing of effectiveness of all infrastructure projects may highly affect for human development. Moreover, Kulinkina *et al*. (2016) highlighted that effective and efficient practices lead to improve health, social and economic benefits to communities. Furthermore, community based management can effectively supply water to humans as the involvement of large number of communities with functioning systems and satisfied users (Bakalian and Wakeman, 2009). Meanwhile, Amer (2004) stated that most of the financial, technical, institutional, social and environmental challenges are arisen while implementing the water supply project. In contrast, technological factor during construction period become a critical factor for effective management of CBOs during past decades (Taylor and Mudege, 1996).

2.2. DEVELOPMENT OF RURAL WATER SUPPLY SECTOR IN SRI LANKA

The concept of water for all by 2025 was established after 1980 (Schouten and Moriarty, 2003). Subsequently, NWS&DB has taken necessary arrangements for efficient and effective involvement with community participation and external stakeholders in Sri Lanka (Rural Water & Sanitation Section [RWSS], 2016). Annual report of National Water Supply and Drainage Board (NWS&DB, 2007) reported that the government has implemented more rural water supply projects with the involvement of CBOs to achieve MDGs throughout the year. Accordingly, RWS division expect to provide access to drinking water facility for further 500,000 dwellers in near future (Fan, 2015).

Community based organisations have become a solution for rural water supply sector, because of arising difficulties due to increasing urban population in Sri Lanka (Mimrose *et al*., 2011).In line with that, the national policy for the rural water supply and sanitation sector has recognized the value of water, and the need for institutional arrangement for the efficient and effective management of facilities with community participation and the stakeholders (Rural Water Supply and Sanitation Division [RWSSD], 2001). Moreover, RWSSD (2001) principles in national policy stated that, CBO and NGO involvement, user management, women participation and private sector involvement should be required for overall project success. Therefore, RWS projects were forced to follow the concepts even though some concepts are not matching with Sri Lankan context (James, 2011).

There is a strong interrelationship between quality construction of water supply schemes during implementation, quality of community mobilization from planning and establishment of support service mechanism during operation and maintenance with the existence of CBOs (Taylor and Mudege, 1996). Further, Wijesundara (2008) found that additional support service mechanism will be needed to enhance the effectiveness of CBO contract system during operation and maintenance phase.

2.3. REVEALS THROUGH PAST EXPERIENCES IN RURAL WATER SUPPLY PROJECTS IN SRI LANKA

The First community water supply and sanitation project was implemented in 1993-1997 with the aid of World Bank as CWSSP-1 (Minnatullah *et al.*, 1998). Meanwhile, Fang (1999) discussed additional training on mobilization strategy, effective CBO involvement in operation and maintenance phase, effective CBO involvement in design phase, additional technical knowledge, additional managerial knowledge and additional focus on institutional arrangements should be developed. Past Asian Development Bank (ADB) projects and World Bank projects revealed those facts.

NWS&DB (2012) revealed that ADB's 4th project aimed to provide access to safe drinking water facility about 330, 293 rural people. According to the Ministry of Finance and Planning (MF&P, 2014), the ADB 4th project implemented by 2003-2013. Moreover, the report concluded that follow-up actions should be developed further to enhance effectiveness of the overall management with the use of effective financial assistance to enhance quality of water, continuous managerial assistance from NWS&DB, effective performance of CBOs and effective relationship between NWS&DB and CBOs. Asian Development Bank (ADB, 2010) project administration manual revealed that NWS&DB and RWS focused on minimizing the challenges in ADB third and fourth projects. Moreover, ADB (2010) identified that management committee has been suggested to take strategies in community participation and community mobilization stages. In addition to aforementioned factors, Muthunayake (2010) found that economic factors, skills of CBOs, motivation factors and external factors are also significantly affect towards the effectiveness of CBOs.

3. RESEARCH METHODOLOGY

The research initiated with a literature synthesis in order to identify significant factors for the effectiveness of CBOs in rural water supply sector in Sri Lanka. For the purpose of realizing the aim of the study, mixed approach was identified as the most suitable method with the intention of identifying most significant factors. As the data collection technique, semi structured interviews based on Delphi technique was carried out to gather the opinion of experts regarding most significant factors towards the effectiveness of CBO management. First round of interviews was carried out with three experts in National Water Supply and Drainage Board who are specialized on client's perspective in Sri Lankan rural water supply. After finishing first round of the interview session, qualitative results were analysed by using content analysis method and quantitative data was analysed with the use of relative importance index (RII) technique and average deviation statistical method.

Questionnaire survey was conducted among 30 respondents in the field of water supply to obtain CBOs' point of view regarding significant factors. Non probability convenience sampling was used in both data collection phases. Finally, gathered data through Delphi second round semi structured interviews and questionnaire survey results were analysed by using RII technique and average deviation statistical analysis technique. In average deviation method, the factors ≥ 0 was considered as significant factors.

4. RESEARCH FINDINGS

Findings asserted 41 significant factors relating to effectiveness of CBO which was reviewed through literature based on past experiences and project completion reports. Two rounds of semi-structured interviews based on Delphi technique were conducted to filter most significant factors. 24 factors and facts on existence of CBOs were identified through first round interviews on client perspective. Further, 9 significant factors were finally found through second round interviews based on client perspective. Subsequently, questionnaire survey results were analysed to identify most significant factors on CBO perspective. Hence, 8 significant factors were filtered based on CBOs' perspective.

4.1. EXISTENCE OF CBOS

According to the findings of literature review and first round expert interviews, collaboration of Quality Construction of water supply Schemes during implementation, Quality community mobilization from planning stage and Establishment of Support service mechanism during Operation and maintenance is paramount to the existence of effective CBO. Key factors which are affecting the existence of CBOs can be shown as in Figure 1.

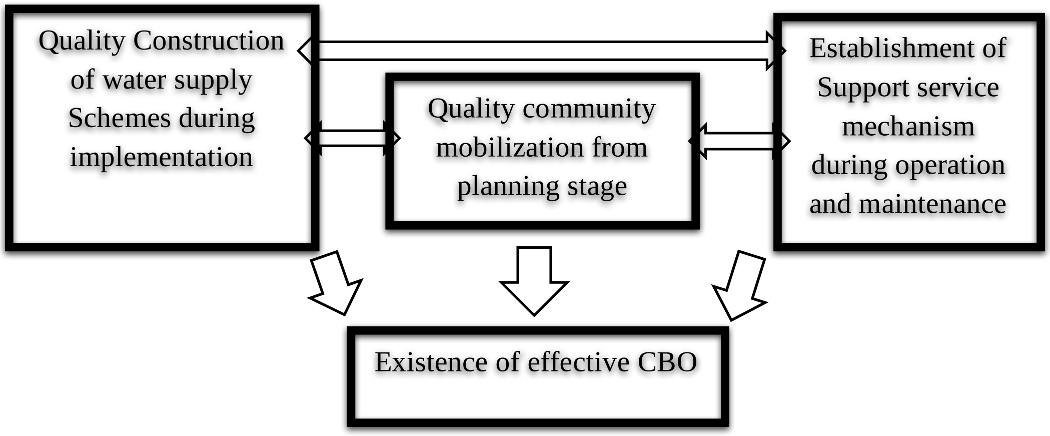

Figure 1: Relationship between Key Factors for Existence of Effective CBO Management

4.2. ANALYSIS OF SIGNIFICANT FACTORS

Second round semi-structured interviews carried out with filtered 24 factors and analysed outcome can be shown as in Table 1. In specific, 22 factors were identified during the second round of semi-structured interviews. Alongside, those factors were taken for the questionnaire survey to cover the CBO opinions with the significance level which is also shown in Table 1.

Table 1: Quantitative Data Analysis

		CBO perspective			Client perspective	
	Factors	**RII%**	**Rank**	**Avg. Dev.**	**RII%**	**Rank**
1	**Institutional**					
1.1	Effective relationship of CBOs with community	83.5%	7	4.3%	66.67%	20
1.2	Difficulty in obtaining expected support from institutions and organizations established to provide backup services	76.5%	13	-2.7%	80.00%	17
1.3	Turnover of trained and skilled staff	85.5%	4	6.3%	73.33%	18
1.4	Continuous managerial assistance to be needed from NWS&DB	71.5%	19	-7.7%	100.00%	1
1.5	Relationship between NWS&DB and CBOs should be developed	79.0%	9	-0.2%	100.00%	1
1.6	Uncertainty regarding the sustainability of voluntary services of scheme caretakers	76.5%	13	-2.7%	66.67%	20
2	**Financial**					
2.1	Effective revenue	86.5%	3	7.3%	100.00%	1
2.2	Effective billing to collection ratio	84.0%	6	4.8%	100.00%	1
2.3	Transparency of accounts	76.5%	13	-2.7%	86.67%	10
3	**Technical**					
3.1	Availability of skill labours	85.5%	4	6.3%	73.33%	18
3.2	Water quality standards	77.5%	11	-1.7%	53.33%	22
3.3	Effective CBO involvement in operation and maintenance phase	78.0%	10	-1.2%	100.00%	1
3.4	Communities' interest decreases over time and as a result, a particular group or a small number of individuals can dominate management and O&M activities	73.5%	18	-5.7%	86.67%	10
3.5	Performance of CBOs should be developed	71.5%	19	-7.7%	100.00%	1
3.6	CBOs' managerial level should be increased	92.0%	1	12.8%	100.00%	1
3.7	Qualified technical staff	76.5%	13	-2.7%	86.67%	10
3.8	Effective CBO involvement in design phase	76.5%	13	-2.7%	86.67%	10
3.9	Additional technical knowledge	71.5%	19	-7.7%	86.67%	10
4	**Social**					
4.1	Effective stakeholder relationship	88.0%	2	8.8%	100.00%	1
4.2	Female involvement & gender balance	71.5%	19	-7.7%	86.67%	10
4.3	Giving chance to poverty	77.5%	11	-1.7%	86.67%	10
5	**Environmental**					
5.1	Monitoring quality of water	83.5%	7	4.3%	100.00%	1

4.2.1. SIGNIFICANT FACTORS IN COB PERSPECTIVE

Finding asserted that effective CBOs' managerial level, effective stakeholder relationship, effective revenue, turnover of trained and skilled staff, availability of skilled labourers, effective billing to collection ratio, monitoring quality of water and effective relationship of CBOs with community as the significant factors under CBO perspective. According to the respondents, if there is an effective CBO managerial level, CBO would be able to manage the organization, community and the water resource efficiently and effectively, after implementation of the project and there will not be any issues in the water supply system. Furthermore, effective support service mechanism leads to build up trustworthiness between the community and the CBOs when there is an effective relationship among the stakeholders. Therefore, that will ensure the community mobilization. Moreover, effective relationship between CBO, community, local authority and other external supporters must be guided to increase the effectiveness of CBO management.

Most of the respondents highlighted that whole of the works during operation and maintenance phase including buying pipes, fittings, other spare parts, water pumps and water purification chemicals, paying salary for staff of the CBOs have to do with the revenue. Therefore, the level of revenue highly impacts towards the effectiveness of the CBO.

In CBOs, sometimes staff tends to turnover due to low salary and other personal matters. As a result, it will affect for the management of CBO since training have to be provided for the new staff at the time of recruitment. During that period CBO may be adversely impacted due to weak staff and management. Therefore, turnover of the staff has become a significant factor. Meanwhile, unavailability of skilled labours will affect to CBO as ordinary community has no experience on pipe laying. It will affect in decreasing the progress of the project and increasing the defects of the work. However, NWS & DB will be given technical assistance during planning to implementation stage. Therefore, CBO management believes that progress of the project will be increased due to the skilled labourers.

Monitoring the quality of water was considered as a paramount factor by all the respondents since CBOs have no authority to monitor the water quality. Therefore, water samples are handed over biennially to NWS & DB in order to check the quality. However, CBOs showed their willingness to monitor water quality if they have support from an agency. Assistance for continuous development are required to refresh the present knowledge and to acquire new techniques on assessment of water quality.

Relationship between CBOs and community was regarded as significant whereas CBOs have to get assistance from community for the implementation of the project and operation and maintenance phase of the project. The benefited areas should provide their fullest support for the project. Moreover, during implementation of the project the whole responsibility should be with CBOs and the client may not involve during that period of the project. Therefore, effective relationship with community facilitates in increasing the effectiveness of CBO management for long time.

4.2.2. SIGNIFICANT FACTORS IN CLIENT PERSPECTIVE

As per the findings, 9 factors including continuous managerial assistance from NWS&DB, effective relationship between NWS&DB and CBOs, effective CBO involvement in operation and maintenance phase and performance of CBOs were determined as significant under the client perspective for effectiveness of CBO. Moreover, effective CBOs' managerial level, effective stakeholder relationship, effective revenue, effective billing to collection ratio and monitoring quality of water were also identified as significant factors under the client perspective and will be discussed in section 4.2.3 since those factors were determined as significant in both perspectives.

Most of the respondents highlighted that continuous managerial assistance should be required from NWS & DB for the effectiveness of CBO. However, CBOs as well as Local Authority do not consider continuous training and development as an important aspect which can be gained through the continuous managerial assistance. Moreover, CBO as well as the community needs external support to implement such training and development programmes. Therefore, the community can be mobilized easily for those programme if such support is available.

All the respondents emphasised that the effective relationship should be there between the NWS&DB and CBOs in order to develop support service mechanism. According to model constitution introduced by NWS&DB to CBOs, the respective CBO was informed to perform at least one audit per year from a reputed institution. However, the CBOs who were not performing well, faced with negative impacts. Similarly, changing of officers is also not happening annually as expected by the constitution. It is also not practical to expect from CBOs to change officers annually as it may affect the management systems and efficiencies.

Moreover, respondents depicted that CBO involvement in operation and maintenance phase can be regarded as a significant factor since CBOs have less capacity to implement the project at the implementation stage resulting poor construction practices during the construction. For instance, if a treatment plant is omitted during planning stage, it is too expensive for CBOs and Local Authority to rectify the impacts at the operation. This leads to managerial issues between community and management authority. Therefore, there must be a strong entrance to the project to enhance the effectiveness of CBO management.

Constructing water supply schemes to up to the standards will build confidence of CBOs during operation and maintenance. However, some construction failures resulted in hardship on community during operation and maintenance stage of schemes. Therefore, high performance will be required to enhance the effectiveness of CBOs.

4.2.3. SIGNIFICANT FACTORS IN BOTH PERSPECTIVES

According to the findings, it was noted that 8 factors were significant under the CBO perspective while 9 factors were identified as significant under the client perspective. Accordingly, 5 factors can be highlighted as significant under both perspectives namely effective revenue, effective billing to collection ratio, effective CBOs' managerial level, monitoring quality of water and effective stakeholder relationship. Accordingly, revenue involves the income earned by the scheme which is a basic indicator of the sustainability and effectiveness whereas the income is essential for maintaining staff, purchase tools, purchasing spare parts, pumps, pipes and chemicals. The profit was being used for the development of the scheme. In client's perspective, they always trust better revenue retains the effectiveness and existence of CBOs.

Billing to collection ratio was considered as significant since CBOs are competitive with NWS&DB in the area of billing and collection. The importance of community involvement in managing resources proves highly successful result in this type of situations. Community has to pay monthly bill to the CBO as it provides the facility to them. If the value of billing to collection ratio is more than one, it will affect for the existence of effective CBO management.

All the respondents agreed with the managerial level of CBOs factor as it enhances the effectiveness of CBO. According to the respondents in managerial level of CBO, water cuts and other information are also displayed in the office. Further, respondents accepted that less complains means availability of more managerial capacity. Further, problems will not be arisen after implementation of the project if CBO leaders can manage the organization and community and the water resource accurately.

Meanwhile, it seems that except the NWS&DB, other implementing agencies have not considered the water quality monitoring as well as the maintenance of water quality standards as the important activities. As a result, CKD (chronicle kidney diseases) problems arose due to poor quality of water. Therefore, this issue mostly impacts for the effectiveness of CBO management. Furthermore, almost all the respondents agreed on maintaining effective stakeholder relationship in order to satisfy the end users as well as to sustain optimally functioning water supply systems.

5. CONCLUSIONS

The lack of access to proper drinking water directly relates to health, hygiene and income opportunities of rural community in developing countries including Sri Lanka. Community engagement in rural water supply project and project management should become essential and the clients should be actively involved. It was identified that, same factors were found as both perspectives agreed including effective revenue, effective billing to collection ratio, effective CBOs' managerial level, effective stakeholder relationship and monitoring quality of water. Other than that, based on client's perspective opinions, continuous managerial assistance to be needed from NWS&DB, relationship between NWS&DB and CBOs, effective CBO involvement in operation and maintenance phase and performance of CBOs should be developed identified as most significant factors. Moreover, in CBO's perspective it was identified effective relationship of CBOs with community, turnover of trained and skilled staff on water supply and availability of skilled labours as most significant factors. As a recommendation, before implementing the project both client and CBOs essential to be consider most significant factors affect to the effectiveness of CBOs to success the overall project and for existence of the CBOs in future.

6. REFERENCES

Ademiluyi, I.A., and Odugbesan, J.A. 2008. Sustainability and impact of community water supply and sanitation programmes in Nigeria: An overview. *African Journal of Agricultural Research,* 3(12), 811-815.

Amer, M.I.A. (2004). *Eighth International Water Technology Conference, community management of rural water supplies system for sustainability of the service* [online]. Alexandria, Egypt: IWTC. Available from: http://www.iwtc.info/2004_pdf/01-6.pdf [Accessed 25 May 2016].

Asian Development bank. (2010). *Project administration manual: Democratic Socialist Republic of Sri Lanka: Jaffna and Kilinochchi Water Supply and Sanitation Project* (Project Number: 37378) [online]. Metro Manila, Philippines: Asian Development Bank. Available from: https://www.adb.org/sites/default/files/linked-documents/37378-01-sri-pam.pdf [Accessed 02 September 2016].

Bakalian, A., and Wakeman, W. (2009). *Post-Construction Support and Sustainability in Community-Managed Rural Water Supply: Case Studies in Peru, Bolivia, and Ghana* (Water Sector Board discussion paper series; no. 14) [online]. Washington, DC: The World Bank Group. Available from: https://openknowledge.worldbank.org/bitstream/handle/10986/17246/487310NWP0Box311PostConstructionRWS.pdf?Sequence=1&isallowed=y [Accessed 15 July 2016].

Batuwitage, G. 2014. Limits to empowerment: case of control and citizen engagement in community driven development in Sri Lanka. *Sri Lanka Journal of Development Administration*, 4, 111–127.

Bethany, L., and Deaton, B. J. 2015. Do water service provision contracts with neighboring communities reduce drinking water risk on Canadian reserves? *Water Resources and Economics,* 11(4), 22-32.

Bolt, E., and Fonseca, C. (2001). *Keep It Working, A field manual to support community management of rural water supplies (Technical paper series / IRC- No.36)* [online]. Delft, Netherlands: IRC publications. Available from: http://www.ircwash.org/sites/default/files/Bolt-2001-Keep.pdf [Accessed 10 July 2016].

Brikke, F. (2000). *Operation and Maintenance of rural water supply and sanitation systems* [online]. Geneva, Switzerland: IRC publications. Available from: http://www.pseau.org/outils/ouvrages/oms_operation_and_maintenance_of_rural_water_supply_and_sanitation_systems_a_training_package_for_managers_and_planners_2000.pdf [Accessed 06 September 2016].

Fan, M. (2015). *Sri Lanka's Water Supply and Sanitation Sector: Achievements and a Way Forward (ADB SOUTH Asia working paper series No. 35)* [online]. Metro Manila, Philippines: Asian Development Bank. Available from: https://www.adb.org/sites/default/files/publication/161289/south-asia-wp-035.pdf [Accessed 14 September 2016].

Fang, A. (1999). *On-site sanitation: An internal review on World Bank sanitation* [online]. New Delhi, India: UNDP-World Bank. Available from: https://www.wsp.org/sites/wsp.org/files/publications/327200723237_onsitesanitation.pdf [Accessed 20 June 2016].

Gbadegesin, A.S., and Olorunfemi, F. B. 2011. Sustainable technological policy options for rural water supply management in selected rural areas of Oyo State, Nigeria. *An International Journal on Management of Environmental Quality,* 22(4), 486 – 501.

International Resource Centre. (2001). *From system to service: scaling up community management: report of the conference* 12 - 13 December 2001, Hague, Netherland. Delft, Netherlands: IRC publications. Available from: http://www.ircwash.org/sites/default/files/IRC-2002-From.pdf [Accessed 14 June 2016].

James, A.J. (2011). *Lessons for rural water supply* [online]. Hague, Netherlands: IRC publications. Available from www.waterservicethatlast.org [Accessed 10 June 2016].

Kulinkina, A.V., Kosinski, K.C., Liss, A., Adjei, M.N., Ayamgah, G.A., Webb, P., Gute, D.M., Plummer, J.D. and Naumova, E.N., 2016. Piped water consumption in Ghana: A case study of temporal and spatial patterns of clean water demand relative to alternative water sources in rural small towns. *Science of the Total Environment,* 559, 291-301.

Laycock, H., Moran, D., Smart,J., Raffaelli, D., and White, P. 2009. Evaluating the cost-effectiveness of conservation: The UK Biodiversity Action Plan. *Biological Conservation,* 142(12), 3120-3127.

Mimrose, D.M.C.S., Gunawardena, E.R.N., and Nayakakorala, H.B. 2011. Assessment of Sustainability of Community Water Supply Projects in Kandy District. *Tropical Agricultural Research*, 23(1), 51-60.

Ministry of Financing & Planning. (2014, September). *Department of project management and monitoring: secondary towns and rural community based water supply & sanitation project report 2014* [online]. Colombo: Ministry of Financing and Planning. Available from: http://www.pmm.gov.lk/resources/Evaluation_Sec_Town_Riral_Commu_Water.pdf [Accessed 12 September 2016].

Minnatullah, K.M., Hewawasam, T., and Gross, A. (1998). *Structured learning in Practice: Lessons from Sri Lanka on Community Water Supply and Sanitation* [online]. Washington, DC: UNDP-world bank. Available from: https://www.wsp.org/sites/wsp.org/files/publications/global_srilanka.pdf [Accessed 16 June 2016].

Muthunayake, P.S. 2010. *Success factors for effective Management of rural water schemes in Sri Lanka* (Unpublished master's thesis). University of Moratuwa, Sri Lanka.

National Water Supply & Drainage Borad. (2007). *National Water Supply & Drainage Borad annual Report 2007* [online].Colombo: National Water Supply & Drainage Board. Available from: http://www.waterboard.lk/web/images/contents/publications/annual/nwsdb_annual_report_2007.pdf [Accessed 16 June 2016].

National Water Supply & Drainage Borad. (2012*). National Water Supply & Drainage Borad annual Report 2012* [online]. Colombo: National Water Supply & Drainage Board. Available from: http://www.waterboard.lk/web/images/annual_reports_2012/annual_report_2012_english.pdf [Accessed 10 June 2016].

Nwankwoala, H.O. 2011. Localizing the strategy for achieving rural water supply and sanitation in Nigeria. *African Journal of Environmental Science and Technology,* 5*(*13), 1170-1176.

Rob, C.D.L., Murray, D., and Brisbois, M.C. 2016. Perspectives of natural resource sector firms on collaborative approaches to governance for water. *Journal of Cleaner Production,* 135, 1117-1128.

Rural Water & Sanitation Section. (2011). *Sri Lanka in profile 2011* [online]. Colombo: National Water Supply & Drainage Board. Available from: http://nwsdbrws.org/wp/ [Accessed 15 June 2016].

Rural Water & Sanitation Section. (2016). *Sri Lanka in profile 2016* [online]. Colombo: National Water Supply & Drainage Board. Available from: http://nwsdbrws.org/wp/ [Accessed 22 June 2016].

Salles, M.C., and Geyer, Y. 2006. *Community-based Organization management.* Pretoria, South Africa: Institute for Democracy in South Africa (IDASA).

Schouten, T., and Moriarty, P. 2003. *Community Water, Community Management: From system to service in rural areas*. London, United Kingdom: ITDG publishing.

Taylor, P., and Mudege, N.R. (1996). *Sustainability: the chaltenge rural water supply and sanitation in Zimbabwe*. [online]. Harare, Zimbabwe: IRC publications. Available from: http://www.ircwash.org/sites/default/files/824-ZW-14635.pdf [Accessed 25 August 2016]

Teare, R., Bandara, C., and Jayawardena, C. 2013. Engaging the rural communities of Sri Lanka in sustainable tourism. *Worldwide Hospitality and Tourism Themes*, 5(5), 464-476.

Wijesundara, T.W.M.L.P. 2008. *Study on CBOs capability for sustainable management of rural water supply schemes.* (Unpublished master's thesis). University of Moratuwa, Sri Lanka

World Bank. (2004). *The International Bank for Reconstruction and Development Global monitoring report 2004* [online]. Washington, DC: The World Bank. Available from: http://siteresources.worldbank.org/INTGLOBALMONITORING/Resources/GMR_ 2004.pdf http://siteresources.worldbank.org/INTGLOBALMONITORING/Resources/GMR_2004.pdf [Accessed 20 June 2016]

Yalegama, S., Chileshe, N. and Ma, T., 2016. Critical success factors for community-driven development projects: A Sri Lankan community perspective. *International Journal of Project Management*, 34(4), 643-659.

SIGNIFICANT MANAGEMENT PRACTICES INFLUENCING THE OCCURRENCE OF WORKPLACE INJURIES: THE CASE OF APPAREL INDUSTRY IN SRI LANKA

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ABSTRACT

Safety culture provides a basis to understand the state of safety in an organization. Further, it gives considerable contribution to the performance of the industry. The management practices; one of components in safety culture also creates a considerable influence on achieving safety. The reviewed literature proved that there is a relationship between management practices and workplace injuries. Workplace injuries can be identified as the bad consequences of the improper safety handling. However, most of the researches have not focused on in-depth investigation of management practices in safety culture and have not looked at the influence which is created on workplace injuries. Therefore, this study aims to identify the critical management practices influencing occurrence of workplace injuries in apparel industry in Sri Lanka.

The quantitative research approach was applied in this research. Questionnaire survey was conducted to collect the data. Nineteen management practices identified through literature are evaluated under six major categories, such as, management commitment, employee participation, training programmes, communication and feedback, hiring practices and rewards system. The questionnaire survey data were analysed using statistical software and Mean Weighted Rating was used to determine significant management practices. As per the statistical test results, nineteen significant management practices influencing occurrence of workplace injuries in apparel industry in Sri Lanka are determined. As the main implication, this research provides a basis for modelling the relationship between different management practices and the occurrence of workplace injuries and, for implementing best management practices in apparel industry in Sri Lanka.

Keywords: *Apparel Industry; Critical Management Practices; Workplace Injuries; Safety Culture; Sri Lanka.*

1. INTRODUCTION

Safety culture is an important concept to understanding the state of the safety within organisations (Vredenburge, 2002). It is specially mentioned about beliefs, values, behaviour, attitudes on the occupational health and safety of the company (Hajmohammad and Vachon, 2014; Clarke, 1999). Consist of managers, supervisors, workforce, company safety policy, rules and procedures created the concept of safety culture (Ali, Abdullah and Subramaniam, 2009). Effective safety of the organisation only can be achieved through the proper management of interrelation between people and technological systems (Kim and Cho, 2016). Management practices consist of different categories such as; training programmes, management commitment, reward system, communication and feedback, hiring practices, and employee participation (Ali *et al.*, 2009). Thus, management can develop a strong safety culture by inspiring certain management practices to reduce the workplace injuries (Reimana and Rollenhagen, 2014). Moreover, worker's belief and management has been linked to safety values and predicting worker work risk behavior and create secure workplace which is

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free from accidents, illnesses, diseases and near misses (Hajmohammad and Vachon, 2014). Work related injuries often create serious problems within the workplace (Yu, Chang and Salvendy, 2004).

According to the statistics of the International Labour Organisation (ILO), around 4,000 workplace accidents are recorded every year in Sri Lanka and Labour Department statistics demonstrated, over 80 Sri Lankans lose their lives from work-related accidents in every year (Warakapitiya, 2016). According to the statistics of the Ministry of Health, around 15% injured patients of total admissions at the Colombo National Hospital was work related injuries and revealed only 1% of from whole estimated accidents (Dissanyake and Fonseka, 2014). Ministry of Labour Relations and Manpower statistics shows, around 17.6% employees work in the manufacturing sector in Sri Lanka (excluding Northern and Eastern provinces) and accidents in manufacturing workplaces are considerable, especially in the apparel industry (Mudugamuwa, 2012). However, lack of regular safety procedures, unsystematic working condition and resource allocation of apparel industry could cause to the workplace injuries in many situations (Reason, 1995).

Therefore, this research is aimed to determine the significant management practices influencing the occurrence of workplace injuries in the apparel industry in Sri Lanka. In addition, this is only a part of a research study in modelling the relationship between different management practices and occurrence of workplace injuries in apparel industry in Sri Lanka.

2. LITERATURE REVIEW

2.1. MANAGEMENT PRACTICES IN SAFETY CULTURE

Culture is a compound phenomenon to study, and also safety culture is the most substantial context of the organisations (Richter and Koch, 2004). Main Purpose of safety culture is to reduce the accidence occurrence and accident investigation. And also, it is increasing acceptance of company safety (Strauch, 2015). There are number of definitions developed by various researches to describe the safety culture (Lee and Harrison, 2000). According to those literature findings, safety culture can be identified in the research as a “combination of beliefs, values and behavioral norms regarding safety and health of human factor (managers, supervisors and workforce) and it is manifest the company safety policy, rules and procedures. Hence, safety culture not only considers about company safety, but also individual and group safety”. Safety management concerns to the safety practises as well as responsibility of safety management system (Ek, Runefors and Borell, 2014). Top management is the main driver of management practices and management is monitored to allocate necessary resources to erecting best practices of management practices (Zhu, Zedtwitz, Assimakopoulos and Fernandes, 2016). And also, management involved to implement the management practices with using rational decisions and open minded decisions about their subordinate (Scott, 1981). The term 'management practices' has several definitions and it can see in every situation and therefore management practices have significant characteristic than other factors. Accordingly, management practices are defined in this research as “an address to the specific improvements of safety behaviour and organisational safety performance to an acceptable level of quality, within budget and on time”.

The increased interest of health and safety management system is directly effecting to the decline in occupational injuries and diseases (Yule, Flin and Murdy, 2007). Therefore, the members of top management have responsibility to ensure organisational management system is concurrent with their regulations (Pilbeam, Doherty, Davidson and Denyer, 2016). Accordance with Cooper's safety culture model, Ek, *et al*. (2014) identified, that there is a bi-directional link between safety culture and safety management. Moreover, safety management practices cause to implement relevant rules and regulations, safety policy at the workplace and regulate existing norms (Nordlof, Wiitavaara, Winblad, Wijk and Weaterling, 2015).Work related accidents could lead to the commencement of the awareness of management practices; because, the international Atomic Energy Agency introduce that term from accident summary report of nuclear plant accident in 1986 (Agumba and Haupt, 2014). Poor safety culture reflects by number of accident occurred within organisation (Nordlof *et al*., 2015). However, the higher level of safety culture could have a positive impact on the decrease of the number of accidents (MdDeros, Ismail, Ghani and MohdYusof, 2014). Ali *et al*. (2009) found that, there is a significant linear relationship between management practices and workplace injuries in industrial zone in Malaysia [$F(6, 61) = 2:28$, $p = 0.04$].

2.2. *DIFFERENT MANAGEMENT PRACTICES INFLUENCING WORKPLACE INJURIES*

Fernandez-Muniz, Montes-Peon and Vazquez-Ordas (2007) stated that, set of management practices used to analyse the effect and relationship with workplace injuries. Level of management commitment and employee engagement can increase through the proper safety management practices. By dissimilarity of different management practices assent the most suitable ways to manage the safety culture of the organisation (Kelloway, Mullen and Francis, 2006). There are different types of management practices categories shown in literature. Among those, most significant management practices which have highly reviewed in previous literature were selected, such as, management commitment, employee participation, training programs, communication and feedback, reward system and hiring practices. Each category consists of several sub factors. Accordingly, twenty eight (28) factors are identified by reviewing key literature (Arboleda, Morrow, Crum, and Shelly, 2003; Barling, 2005; Harter, Schmidt and Killham, 2006; Rich, Lepine and Crewford, 2010; Lui, Liu and Ling, 2011; Wachter and Yorio, 2013; Biggs, Banks, Davey and Freeman, 2013; Subramaniam *et al*., 2016; Taufek, Zulkifle, and Kadir, 2016).

Table 1 presents the sub factors of management practices influencing the occurrence of workplace injuries.

Table 1: Sub Factors of Management Practices

Management Practices	**Sub Factors**
Management Commitment	Management participation for HandS practices
	Management commitment for safety awareness
	Create future planning for safety
Employee Participation	Involve to creating safe work instruction
	Can influence on STOP work criteria
	Devising solutions to incidence that resulted from human error
	Performing safety observations of other employees
	Conducting accident investigation
	Hiring for safety of their peers
Training programmes	Formally training on the safety aspects
	Number of hours of formal safety training
	Frequency of safety training
	Training elements of hazard recognition and avoidance
Communication and feedback	Information of new or revised safety rules
	Information on potential hazards in the workplace related
	Information about the importance of working safely
	Information about safety incidents experience in the similar organisations
	Information on near misers by other employee
	Sharing the results of the safety investigations among workforce
Hiring Practices	Safety values and beliefs of the organisation
	Only the best people are hired to work in the organisation
	Job applicants for job offer
	Physical stating examines for job applicants
Rewards System	Giving out monetary rewards for fewer accidents
	Giving out non-monetary rewards for fewer accidents
	Giving out incentives based on individual's safety performance.
	Giving out incentives based on group's safety performance.
	Adopting punishment when a worker is found to have violated safety measures on site

By reviewing key literature, 28 sub factors are identified relating to six major categories which are used in subsequent analysis. The methodology adopted is described in Section 3.

3. RESEARCH METHODOLOGY

To accomplish the research aim, quantitative research approach was followed which was identified as the most appropriate method for gathering and analysing the data. The data were collected through questionnaire survey. Managerial and executive level professionals in apparel industry, such as, safety officers, environment, health and safety managers, etc were randomly selected for data collection and, seventy-five (75) questionnaires were distributed. Sixty-two (62) numbers of professionals were responded to the questionnaire survey by maintaining a high response rate of 83%.

Figure 1 illustrates the experience of the managerial and executive level people in occupational safety and health sector in apparel industry. There, 16% of workers have experience less than 5 years, 25% have experience in the field for 5-10 years. 12% of them hold 10-15 years of experience and 9% of the respondents have experience more than 15 years in the field as shown in Figure 1.

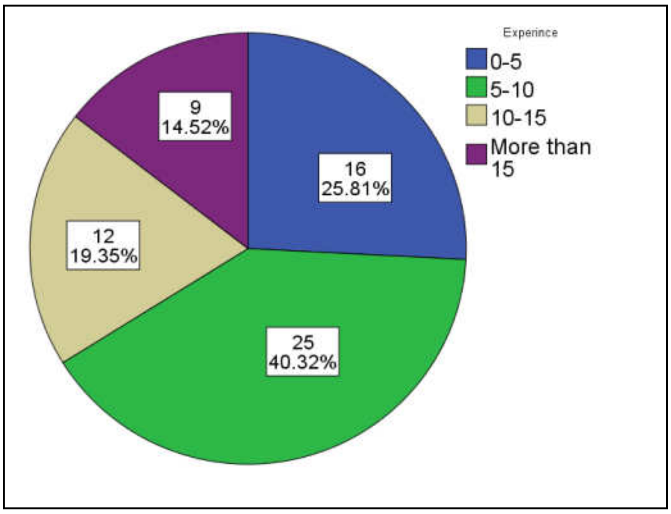

Figure 1: Work Experience of Respondents

The respondents were asked to rank the influence of management practices on the occurrence of workplace injuries using a 5 point Likert scale. The software program SPSS-23 was used for to calculate the Mean Weighted Rating for determining the significant management practices. According to the Sobh and Perry (2006), mean weighted rate (refer Eq. 01) is the sum of weightings which are divided by the total number of respondents.

$$MR = \sum_{i=1}^{5}(Fi\ x\ \%R) \qquad \textit{(Eq. 01)}$$

Where: MR = Mean Rating for an attribute; Fi = Frequency of responses for an attribute (ranging from 1-5); %R = Percentage response to rating point of an attribute.

According to the Saunders, Lewis, Thornhill (2009), the inter-quartile range (IQR) of mean value is normally chosen where there are extreme data values that need to be ignored. The significant factors under each category was analysed based on mean rate value.

$$IQR = Q3 - Q1 \qquad \textit{(Eq. 02)}$$

Further, most of the researches stated that there is no considerable value if it is less than mean rating value of 3.00. Result of this analysis is tabulated for each category and results are interpreted based on calculations.

4. RESEARCH FINDINGS AND DISCUSSION

The significant factors are assessed under six sub categories of management practices of safety culture. Mean weighted rating technique was used with the support of SPSS to select the significant management practices in each category.

4.1. *TRAINING AND SUPERVISION*

According to the literature findings training and supervision category consist with four sub factors such as formal training on the safety aspect, number of hours of formal training, frequency of safety training and training elements of hazard recognition and avoidance. The test results of mean weighed rating are mentioned in Table 2.

Table 2: Test Results of Training and Supervision

No	Sub Factors	No	Min. Mean	Max. Mean	Mean	Std. Dev.
1	Formal training on the safety aspect	62	2	5	4.35	0.889
2	Training elements of Hazard recognition and avoidance	62	1	5	4.00	0.992
3	Frequency of safety training	62	1	5	3.76	0.900
4	Number of hours of formal safety training	62	1	5	2.89	1.392

Results of the survey clearly denoted that formal training on the safety aspect has the highest mean weighted rating value of 4.35 (SD = 0.889). Further, 56.45% of the respondents ranked this factor as ‘Highly Significant’. Mean weighted rating value of training elements of hazard recognition and avoidance is 4.00 (SD = 0.992) and 30.64% of the respondent selected this factor as ‘Highly Significant’. Frequency of safety training calculated mean weighted rating value is 3.76 (SD = 0.900) and around 19.35% respondents rank it as ‘Highly Significant’. Number of hours of formal safety training mean weighted rating value calculated as 2.89 (SD = 1.392) and it was rejected due to the lower IQR value of mean weighted rating value (IQR < 3.00). According to survey results, respondents were not considered about number of hours of formal safety training as a significant factor among the other factors. High training frequency could cause to update knowledge on safety information, but long training hours may not do it effectively.

As per the results, three factors were selected as significant management practices such as; formal training on the safety aspect, frequency of the safety training and training elements of hazard recognition and avoidance.

4.2. *EMPLOYEE PARTICIPATION*

This category consists with six sub factors such as; involve to create safe work instruction, can influence on STOP work criteria, devising solutions to incidence that resulted from human error, performing safety observations of other employees, conducting accident investigation and hiring for safety of their peers.

The result of discussed status including weighted mean and standard deviation of employee participation related factors are shown in Table 3.

Table 3: Test Results of Employee Participation

No	Sub Factors	No	Min Mean	Max Mean	Mean	Std. Dev.
1	Involvement to create safety work instruction	62	2	5	4.19	0.827
2	Conducting accident investigation	62	2	5	4.13	0.896
3	Devising solutions to incidence that resulted in human error	62	1	5	2.97	1.267
4	STOP work criteria	62	1	5	2.95	1.26
5	Performing safety observation of other employee	62	1	5	2.94	1.458
6	Hiring safety of their peers	62	1	5	2.82	1.153

Among the other factors, involve to create safety work instruction is the most significant factor witch to be mean weighted rating value of 4.19 and standard deviation of 0.827. Further, 40.32% of respondents are ranked this factor as ‘Highly Significant’. Conducting accident investigation showed MWR value of 3.13 and standard deviation of 0.896 as the second significant factor. According to the lower IQR of mean weighted rating value

(IQR< 3.00), four factors were rejected, such as; devising solutions to incidence that resulted from human error, STOP work criteria, performing safety observations of other employee and hiring safety of their peers. Thus, two factors were selected as significant management practices such as; involvement to create safety work instruction and conducting accident investigation.

4.3. *COMMUNICATION AND FEEDBACK*

Information of new or revised safety rules, information on potential hazards in the workplace related, information about the importance of working safely, information about safety incidents experience in the similar organisations, information on near misses by other employee and sharing the results of the safety investigations among workforce are the sub factors identified in this category.

Table 4: Test Results of Communication and Feedback

No	Sub Factors	No	Min. Mean	Max. Mean	Mean	Std. Dev.
1	Information about the important of working safety	62	1	5	4.26	0.867
2	Information of new or revised safety rules	62	2	5	4.15	0.921
3	Information on potential hazard in the workplace	62	2	5	4.08	0.911
4	Sharing the results of safety investigation among workforce	62	2	5	4.06	0.939
5	Information of near misers by another employee	62	1	5	3.9	1.051
6	Information about safety incidents experience in the similar companies	60	1	5	3.77	0.998

According to the test results shown in Table 4, all the factors were identified as significant factors. Information about the importance of working safety is the most significant factor which showed mean weighted rating value of 4.26 and standard deviation of 0.867. Further, 45.16% of respondents are ranked this factor as 'Highly Significant'. Information of new or revised safety rules showed mean weighted rating value of 4.15 and standard deviation of 0.921 as the second significant factor. Information on potential hazards in the workplace was third significant factor with the 4.08 of mean weighted rating value and 0.911 of standard deviation. Further, 38.70% of responders ranked this factor as 'Highly Significant'. Further, sharing the results of safety investigation among workforce, information of near misers by another employee and information about safety incidents experience in the similar companies also selected as significant factors with the mean weighted rating values of 4.06, 3.9 and 3.77 respectively.

4.4. *REWARD SYSTEM*

This category consists of five sub factors such as; giving out monetary rewards for fewer accidents, giving out non-monetary rewards for fewer accidents, giving out incentives based on individual's safety performance, giving out incentives based on group's safety performance and adopting punishment when a worker is found to have violated safety measures on site. Mean Weighted Rating of each facto is evaluated as shown in Table 5.

As the Table 5 illustrates, two factors were determined as significant factors such as, non-monetary rewards for fewer accidents and giving out incentives based on group's safety performance. Among those, non-monetary rewards for fewer accidents is the most significant factor which showed mean rating value of 3.48. Further, 11.29% of respondents ranked this factor as 'Highly Significant'.

Table 5: Test Results of Reward System

No	Sub Factors	No	Min. Mean	Max. Mean	Mean	Std. Dev.
1	Non-monetary rewards for fewer accidents	62	1	5	3.48	0.901
2	Giving out incentives based on group safety performance	62	1	5	3.48	1.067
3	Giving monetary rewards for fewer accidents	62	1	5	2.98	1.079
4	Adopting punishments when the worker violated safety measures	62	1	5	2.98	1.287
5	Individual Performance	62	1	5	2.95	1.137

Further, giving out incentives based on group's safety performance also showed highest ranking with the respective Mean Weighted Values of 3.48 with the 14.51% response rate as 'Highly Significant'.

4.5. Management Commitment

According to the literature reviewed, management commitment consists of three sub factors such as; management participation for health and safety (HandS) practices, management commitment for safety awareness and create future planning for safety.

Table 6: Test Results of Management Commitment

No	Sub Factors	No	Min. Mean	Max. Mean	Mean	Std. Dev.
1	Management participation for HandS practices	62	2	5	4.44	0.842
2	Management commitment for safety awareness	62	2	5	4.42	0.841
3	Creating future planning for safety	62	2	5	4.35	0.832

The result shown in Table 6 proved that all three factors are statistically significant based on Mean Weighted Values calculated. Among those, management participation for HandS practices is the most significant factor which has mean rating value of 4.44 and standard deviation of 0.842. Further 59.67% of respondent are ranked this factor as 'Highly Significant'. Management commitment for safety awareness showed mean rating value of 4.42 and standard deviation of 0.841 and selected as the second significant factor with 59.67% of respondent ranking. Create future planning for safety is the selected as third significant factor which has mean rating value of 4.35 with standard deviation of 0.832. 54.83% of respondents ranked this factor as 'Highly Significant'.

4.6. Hiring Practices

This consists of four sub factors such as; safety values and beliefs of the organisation, only the best people are hired to work in the organisation, job applicants for job offer and physical stating examines for job applicants.

Table 7: Test Results of Hiring Practices

No	Sub Factors	No	Min. Mean	Max. Mean	Mean	Std. Dev.
1	Safety values and beliefs of the organisation	62	1	5	3.9	0.863
2	Only the best people are hired to work in the company	62	1	21	3.37	2.543
3	Physical stating examines for job applicant	62	1	5	3.27	1.23
4	Job applicant of the job offer	62	1	5	2.97	1.13

The Table 7 illustrate the test result of hiring practices. Among the other factors, safety values and beliefs of the organisation has highest mean weighted rating value of 3.9 and standard deviation of 0.863. Further, 24.19% are ranked the factor as 'Highly Significant'. Only the best people are hired to work in the organisation is the second significant factor which has 3.37 of mean weighted rating value and 2.543 of standard deviation and 11.29% of respondents ranked the factor a ‘Highly Significant’. Physical stating examines for job applicants is the third significant factor which has mean rating value of 3.27 and standard deviation of 1.23. Further, 19.35% of respondents ranked the factor as ‘Highly Significant’.

4.7. *REJECTED FACTORS*

Nine factors are rejected as 'statistically insignificant' based on IQR of mean rating value such as, number of hours of formal safety training, devising solutions to incidence that resulted in human error, stop work criteria, performing safety observation of other employees, hiring safety of their peers, giving monetary rewards for fewer accidents, adopting punishments when the worker violated safety, individual performance and job applicant of the job offer as shown in Table 8.

Table 8: Rejected Factors

No	Sub Factors	No	Min. Mean	Max. Mean	Mean	Std. Dev.
1	Number of hours of formal safety training	62	1	5	2.89	1.392
2	Devising solutions to incidence that resulted in human error	62	1	5	2.97	1.267
3	STOP work criteria	62	1	5	2.95	1.26
4	Performing safety observation of other employees	62	1	5	2.94	1.458
5	Hiring safety of their peers	62	1	5	2.82	1.153
6	Giving monetary rewards for fewer accidents	62	1	5	2.98	1.079
7	Adopting punishments when the worker violated safety	62	1	5	2.98	1.287
8	Individual Performance	62	1	5	2.95	1.137
9	Job applicant of the job offer	62	1	5	2.97	1.13

4.8. *SIGNIFICANT MANAGEMENT PRACTICES SELECTED FOR NEXT STAGE OF THE RESEARCH*

Based on statistical analysis, nineteen (19) factors are determined as 'statistically significant factors' relating to the six major categories. As statistical analysis showed, formal training on the safety aspect, training elements of hazard recognition and avoidance and frequency of safety training are the statistically significant factors in training and supervision. Communication and feedback related significant practices include information about the important of working safety, information of new or revised safety rules, information on potential hazard in the workplace, sharing the results of safety investigation among workforce, information of near misers by another employee and information about safety incidents experience in the similar companies. Further, management participation for HandS practices, management commitment for safety awareness and creating future planning for safety are other significant factors related to management commitment. Employee participation includes two significant factors such as involvement to create safety work instruction and conducting accident investigation.

Further, non-monetary rewards for fewer accidents, giving out incentives based on group safety performance, safety values and beliefs of the organisation, only the best are people hired to work in the company and physical stating examines for job applicant are the other significant factors related to reward system and hiring practices respectively.

The selected factors are shown in Figure 2.

The nineteen (19) statistically significant management practices which were determined at the first stage of data analysis were selected for the next stage of the research for modelling the relationship between different management practices and occurrence of workplace injuries in apparel industry in Sri Lanka.

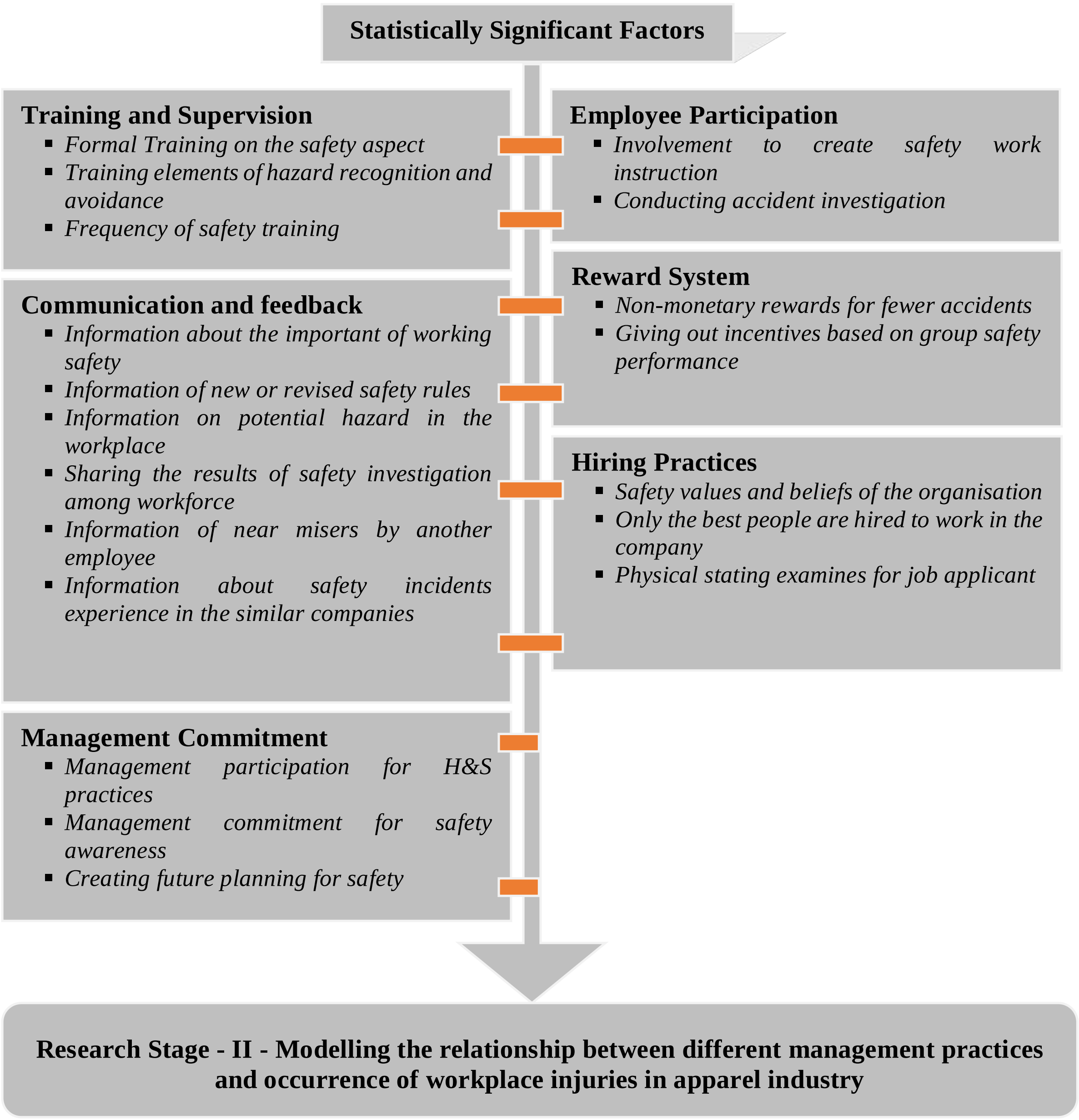

Figure 2: Significant Management Practices Selected for Research Stage - II

5. SUMMARY

This research aimed to determine the statistically significant management practices influencing occurrence of workplace injuries in apparel industry in Sri Lanka. The research discloses the critical factors by using Mean Weighted Rating analysis. Accordingly, nineteen factors were identified as statistically significant factors whilst nine factors were rejected as statistically insignificant. As this paper presents the initial findings of the research, the identified factors will be used for statistical modelling of the relationship between different management practices and occurrence of workplace injuries in apparel industry in Sri Lanka as the next stage of data analysis. However, at this stage, the findings can be used as a basis to implement an effective management practices in apparel industry for assuring safety environment with fewer occurrence of workplace injuries.

6. REFERENCES

Agumba, J.N. and Haupt, T. 2014. The implementation of health and safety practices: Do demographic attributes matter? *Journal of Engineering, Design and Technology*, 12(4), 530-550.

Ali, H., Abdullah, N. and Subramaniam, C. 2009. Management practice in safety culture and its influence on workplace injury. Disaster Prevention and Management: *An International Journal*, 18(5), 470-477.

Arboleda, A., Morrow, P. C., Crum, M. R., and Shelley, M. C. 2003. Management practices as antecedents of safety culture within the trucking industry: similarities and differences by hierarchical level. *Journal of Safety Research*, 34(2), 189-197.

Barling, J. 2005. Inspired workers are healthy workers. *Canadian Healthcare Manager*, 12(3), 39.

Biggs, S. E., Banks, T. D., Davey, J. D., and Freeman, J. E. 2013. Safety leaders' perceptions of safety culture in a large Australasian construction organisation. *Safety Science*, 52, 3-12.

Clarke, S. 1999. Perceptions of organizational safety: implications for the development of safety culture. *Journal of Organizational Behavior*, 20(2), 185-198.

Dissanyake, C. and Fonseka, R. T. 2014. Blood on the factory floor – industrial accidents soar. *The Sunday Times*. 2014, January 12

Ek, Å., Runefors, M. and Borell, J. 2014. Relationships between safety culture aspects – A work process to enable interpretation. *Marine Policy*, 44, 179-186.

Fernández-Muñiz, B., Montes-Peón, J. M. and Vázquez-Ordás, C. J. 2007. Safety culture: Analysis of the causal relationships between its key dimensions. *Journal of Safety Research*, 38(6), 627-641.

Hajmohammad, S. and Vachon, S., 2014. Safety Culture: A Catalyst for Sustainable Development. *Journal of Business Ethics*, 123:2, 263-281

Harter, J., Schmidt, F., Killham, E., and Asplund, J., 2006. *Q12 Meta-analysis. The Gallup Organization*, Washington, DC.

Kelloway, E. K., Mullen, J. and Francis, L. 2006. Divergent effects of transformational and passive leadership on employee safety. *Journal of Occupational Health Psychology*, 11(1), 76-86.

Kim, W. and Cho, H. 2016. Unions, Health and Safety Committees, and Workplace Accidents in the Korean Manufacturing Sector. *Safety and Health at Work*, 7(2), 161-165.

Lai, D. N., Liu, M., and Ling, F. Y. 2011. A comparative study on adopting human resource practices for safety management on construction projects in the United States and Singapore. *International Journal of Project Management*, *29*(8), 1018-1032.

Lee, T. and Harrison, K. 2000. Assessing safety culture in nuclear power stations. *Safety Science*, 34(1-3), 61-97.

MdDeros, B., Ismail, A.R., Ghani, J.A. and MohdYusof, M.Y. 2014, "Conformity to occupational safety and health regulations in Malaysian small and medium enterprises", *Journal of Applied Sciences*, 11(3), 499-504.

Mudugamuwa, M. 2012. Work related accidents: Construction, manufacturing sectors most dangerous sectors. *The Island*. (2012, May 7)

Nordlöf, H., Wiitavaara, B., Winblad, U., Wijk, K. and Westerling, R. 2015. Safety culture and reasons for risk-taking at a large steel-manufacturing company: Investigating the worker perspective. *Safety Science*, 73, 126-135.

Pilbeam, C., Doherty, N., Davidson, R.andDenyer, D. 2016. Safety leadership practices for organizational safety compliance: Developing a research agenda from a review of the literature. *Safety Science*, 86, 110-121.

Reason, J. 1995. A systems approach to organizational error. *Ergonomics*, 38(8), 1708-1721.

Reiman, T.and Rollenhagen, C. 2014. Does the concept of safety culture help or hinder systems thinking in safety? *Accident Analysis and Prevention*, 68, 5-15.

Rich, B. L., Lepine, J. A. and Crawford, E. R. 2010. Job Engagement: Antecedents and Effects on Job Performance. *Academy of Management Journal*, *53*(3), 617-635.

Richter, A. and Koch, C. 2004. Integration, differentiation and ambiguity in safety cultures. *Safety Science*, 42(8), 703-722.

Saunders, M., Lewis, P. and Thornhill, A. 2009. *Research methods for business students*, 5th ed. Mark Saunders, Philip Lewis, Adrian Thornhill

Scott, R.W. 1981. *Organisations: Rational, Natural and Open Systems*, Prentice Hall, Englewood Cliffs, NJ.

Sobh, R. and Perry, C. 2006. Research design and data analysis in realism research of Marketing. *European Journal*, 40(11/12), 1194 - 1209.

Strauch, B. 2015. Can we examine safety culture in accident investigations, or should we? *Safety Science*, 77, 102-111.

Subramaniam, C., Mohd. Shamsudin, F., Mohd Zin, M. L., Sri Ramalu, S. and Hassan, Z. 2016. Safety management practices and safety compliance in small medium enterprises. *Asia-Pacific Journal of Business Administration*, 8(3), 226-244.

Taufek, F. H., Zulkifle, Z. B. and Kadir, S. Z. 2016. Safety and Health Practices and Injury Management in Manufacturing Industry. *Procedia Economics and Finance*, 35, 705-712.

Vredenburgh, A. G. 2002. Organizational safety. *Journal of Safety Research*, 33(2), 259-276.

Wachter, J. K. and Yorio, P. L. 2013. A system of safety management practices and worker engagement for reducing and preventing accidents: An empirical and theoretical investigation. *Accident Analysis and Prevention*, *68*, 117-130.

Warakapitiya, K. 2016. Industrial accidents on the rise. *The Sunday Times*. P.16. (2016, July 24)

Yu, R.F., Chan, A.H.S. and Salvendy, G. 2004, “Chinese perception of implied hazard of signal words and surround shapes”, *Human Factors and Ergonomics in Manufacturing*, 14(1), 69-80.

Yule, S., Flin,R. and Murdy,A. 2007, The role of management and safety climate in preventing risk-taking at work”, *International Journal of Risk Assessment and Management*, 7(2), 137-151.

Zhu, A. Y., Von Zedtwitz, M., Assimakopoulos, D. and Fernandes, K. 2016. The impact of organizational culture on Concurrent Engineering, Design-for-Safety, and product safety performance. *International Journal of Production Economics*, 176, 69-81.

SOFTWARE CAPABILITIES OF SRI LANKAN ARCHITECTURAL PROFESSIONALS FOR BIM ADOPTION

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ABSTRACT

Building Information Modelling (BIM) is a technological and attainable concept, which has upgraded the construction industry into a more diligent industry. It has globalized in a way, which make innovative, cost effective, energy efficient, sustainable and practicable products as well as faster and more effective processes. By the aid of various BIM software packages connected with different disciplines for various stages, this realisation could achieve more accomplishments. However, majority of practitioners of the construction industry only have competencies over the traditional software and this is also one of the major constraints for not applying BIM to the construction organizations. Therefore, construction practitioners must have proficiency over the competencies required for effective BIM products. Interestingly, there seems that many BIM tools have similarities to conventional tools. Software developers over the world have developed several BIM software tools for each of the disciplines which are currently involved in the projects. Majority of the recently completed BIM assignments have typically used software suites belonging to Autodesk software developers, as such there is high potential of using such suits in early BIM projects in Sri Lanka. Hence, this study aims to identify extent to which BIM like activities in conventional tools are practiced in the Sri Lankan industry.

It synthesizes the findings of a literature review on software disciplines which are used in the BIM implementation by various professionals in each of the stages of project sequence. Through the desk study and the expert interviews a qualitative study conducted to identify the gap between 3D BIM modelling competencies with the current competency level of the Sri Lankan Architect. It was found that, working in Revit is more like building a building than drawing one. Further, the great thing about Revit is that all the objects work not the same as in AutoCAD. So if designer know how to place a wall in CAD, but designer can't place a wall in Revit. Because it use object oriented method. Fundamentals are just about the same, there are of course a few differences but can work through those fairly easily. According to the summary, can be concluded that Sri Lankan Architects much familiar about few of the task. But, the handling/performing such activities much differ than what they follow.

Keywords: *Architects' activities; AutoCAD; Building Information Modelling; Revit; Sri Lankan Architects' Competency.*

1. INTRODUCTION

BIM implementation in the construction industry will result in a great change for the professionals as well (Harris , 2011). Reddy (2011) stated that although in practice, BIM is considered as a three-dimensional (3-D) computer aided design software program; in reality BIM is a process improvement approach that influences data to analyze and predict results during different phases of the building life cycle. Hence, transitioning to BIM is "hard and expensive" which may create havoc and frustration. Moreover, implementation is challenging both technical (hardware/software) and firm cultural-wise. This basically means, educate everyone in the office, and assign separate tasks, increasing hardware and buying expensive BIM software (Deutsch, 2011). Accordingly, Jayasena and Weddikkara (2012) identified that there is lack of technical knowledge in getting the best use of BIM. However, in-depth technical knowledge is not necessary to perform BIM. By using developed initiative software the user can work with BIM effectively. Therefore, the profession of architecture is the first step to adopt BIM. When it comes to the adoption of BIM the architectural firm will

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have to perform and incorporate the technology into the firm's business model. This will demand changes in project delivery methods and the composition of the firm's staff.

During the last two decades when the application of BIM tools over the traditional tools is considered at beginning some United Kingdom (UK) architect firms have used 2D Computer Aided Design (CAD) tools. However, with this 2D drafting bring inefficiency situation for the building construction process such as timescales, duplication, lack of rigorous design process, lack of effective design management and communication etc. (Liker, 2004; Koskela, 2003).

When considering BIM implementation capability and the BIM Software Environment (BIMSE) of the Sri Lanka Rogers *et al.* (2015) discovered that although currently construction industry in the Sri Lanka is in wealthy manner, but it is poor in the BIM adoption to the construction. Due to the less identical systems and being a developing country, there is a need to appliance strategies to embrace BIM.

Focusing on the Information Technology (IT) literacy in the country relating to BIM, Jayasena and Weddikkara (2012) emphasized that technology adoption is not the challenge with a reasonably high IT knowledge and Architecture, Engineering and Construction (AEC) professionals with a fair computer competence. The real problem is resistant to change. The Architects are not willing to change according to the environmental change. However, Sri Lankan professionals are still using the traditional methods for carrying out designs and measurement works, which include taking-off from the drawings and then transferring dimensions into spread sheets for issuing out the cost reports to other parties and for design purposes use 2D CAD drawings. Therefore, the identification of the current practice on Architects on their profession and the level of identified competencies will result to development of the Architects who are willing to move towards BIM.

2. CURRENT USE OF IT IN CONSTRUCTION STAGES

The Royal Institute of British Architects (RIBA, 2012) has mentioned that the project life cycle basically consist of seven phases; preparation, design, pre-construction, construction, use and R&D. As Omar *et al.* (2014) have identified that project consist in four phase initiation, planning/design, and execution, controlling and closing. Each phase is executed for the sake of successfulness of the project. Both RIBA (2012) and Omar *et al.* (2014) have identified that the design phase is the most significant chapter that would influence overall project life cycle. This cover task such as concept, design development and technical design. In this phase, ICT and BIM impact is high.

Sommeriville and Craig (2006) have discovered that IT play a major role in the various stages of a construction projects if considered from three standpoints: i.e. Pre-tender, post tender and post-completion. Also it highly affects to procurement and the eventual routes in each project and organization. Finally, there is a need to consider the impact IT has on the humans involved in the delivery of the construction project.

Furthermore, identified professionals who are interest on applications. Table 1, shows that different software application used by main function within the construction company

Table 1: IT Tools, by Construction Project Functions and Phases with Users

Management Function	Top Management	Estimating	Scheduling & Planning	Project Management	Operations Management	Designs Aspects
Typical Task	• Accounting Software (Microsoft Office Package) • Web Portals	• Estimating Software • Automated Quantity Take-off • CAD Document with Microsoft Excel	• CPMex. Microsoft Project, Primavera • Monte Carlo Simulation • 3D CAD • 4D CAD • Microsoft Excel	• CPM • Accounting Software • Web Portals	• Knowledge mangement • Electronic Books • Mobile Computers	• Autodesk Architecture • Autodesk Structure, MEP • 3D CAD
Project Phases (RIBA)	• Inception • Feasibility	• Outline Proposals • Site Operation	• Site Operations	• Site operation • Outline Proposal	• Site Operation	• Schematic Design

Management Function	Top Management	Estimating	Scheduling & Planning	Project Management	Operations Management	Designs Aspects
	• Sketch Planning		• Outline Proposal			• Detail Design • Outline Proposal
IT Tools (Solutions)	• Accounting Software (Microsoft Office Package) Web Portals	• Estimating Software • Automated Quantity take-off • Interoperability with CAD Excel	• Microsoft Project, Primavera • 3D CAD • 4D CAD • Microsoft Excel	• CPM • Accounting Software • Web Portals	• Knowledge management • Electronic Books • Mobile Computers	• Autodesk Architecture • Autodesk Structure, MEP • Sketch up • 3D CAD
Users	• Top Mangers	• QS • Engineers	• Project Mangers • Quantity Surveyors	• Project Mangers • Engineers • QS		• Architectors • Draftsmen • Contractors • QS

3. BIM TERMINOLOGY

According to Olatunji (2014) there have been several perspectives on the potentiality of BIM deliverables, most popularly in the design and construction context. In addition, National Institute of Building Sciences mentioned that in the construction perspective the BIM is not only a software implementation. It is a different way of thinking. BIM is a process which is requires a change from the general process with the project participants (including architects, surveyors and contractors) with effective working environment in common pool.

According to the design perspective BIM is a development of a computerized model which is mimic the construction process and operation of facility.

> *"The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital re-presentation of the facility, from which views and data appropriate to various users' needs can be extracted and analysed to generate information that can be used to make decisions and improve the process of delivering the facility. The process of using BIM models to improve the planning, design and construction process is increasingly being referred to as Virtual Design and Construction (VDC)"* (Associated General Contractors [AGC], 2006: p. 3)

Furthermore, Aranda-Mena *et al*. (2009) believed that this helps to shift to the professionals who still playing in the industry with separate information pools using mismatched different applications. As above mentioned, through the building modelling it provide digital world involving a digital prototype of the model.

4. TRADITIONAL SOFTWARE TOOLS VS BIM TOOLS

The involvement of BIM allows a lot of separated tasks to get synchronized and bring up the ultimate unity of data handling. The 3D visualized drawings, information structures, design precautions and material take-offs are not only automated but also carefully examined for conflicts (Haron, 2013). In other words, compared with conventional software, BIM assisted information structures have more advanced advantages. Hence, each BIM assisted application is well arranged and has the capability to function at higher pace providing more efficiency. Moreover, the expected quality of the output is considerably high.

Due to better design and quality of the item faster and more effective process can be achieved. Benjaoran and Bhokha (2010) have identified that it is a collaboration tool for all project participants. Furthermore, Gong and Caldas (2011) have proposed that BIM is a process that deduct in manual efforts like time and cost saving. Moreover, Gu and London (2010) have mentioned that it identify possibility of conflicts and risk that would be arisen in construction.

According to Sacks and Barak (2007) the replacement of 2D design applications by 3D modelling has been able to reduce working hours of three separated projects by 21%, 55% and 61% respectively. CRCCI (2009) has stated that switching to BIM, demands the adaptations to new digital environment. In operations of traditional systems, corrections made one section would need to be reapplied to the rest of the sections because of their independence. While those conventional applications had independent graphics, BIM supports interrelated graphic and data structures where editing one part would auto update the rest. Therefore, the manually connected hard copies are comparatively leaps and bounds behind BIM assisted applications.

Furthermore, Chelson (2010) has argued that the collaboration of data bases is able to act as one active unit and operate over a wide range of areas need to be looked after. Moreover, Chelson stated that the use of 3D modelling benefited to each and every step of a massive construction project. In addition, BIM tools include and illustrate the association or relationship between each element. Even though, traditional models are still produced through building modelling, they can also be fed with relevant information easing up the overall process. And in addition to that information can be arranged in accordance to user’s requirements.

4.1. BIM TOOLS

Table 2 shows BIM tools used in the building works and the civil and infrastructure engineering.

Table 2: BIM Tools

Building Works Tools	
Design Software	Although there are huge software packages on Designing, most Common Practice on designing is ArchiCAD and Revit Package. Graphisoft (2016) have proposed that architects can explore their design idea without compromising on documentation precision and quality due to ArchiCAD. ArchiCAD has begun with version 13.0, now it updated to version 20. Also, ArchiCAD is made by architects for architects, guaranteeing a BIM authoring tool that offers the most natural and intuitive work environment, to achieve the best design workflow. Revit also a BIM tool which is greatly used in AEC industry to design building and its components. Other than that, it provides collaborative capabilities which integrate all the disciplines and enables the design team, the contractor, and the client to exchange diverse ideas and approaches which help to simplify the way buildings are built (Autodesk, Revit, 2016; Autodesk, 2013).
Structural Engineering	Revit Structure and Tekla Structure can be identified as most Commonly used software packages for effective Structural designing. Tekla Structure is a BIM software that enables the creation and management of accurately detailed, highly constructible 3D structural models regardless of material or structural complexity. The models can cover the entire building process from conceptual design to fabrication, erection and construction management. In addition to that Peddinghaus (2016) has stated that modelling with Tekla Structures is the most advanced and integrated way to detail and fabricate all steel structures, such as commercial buildings, industrial plants, sports stadiums, offshore platforms and jackets including miscellaneous steel work. Further Tekla uses CAD standards to create fully interactive structures for all construction projects.
Building Services	Many researches have identifies that there are several applications used for building services such as Revit MEP, Tekla, Bentley package and DD CAD package. As a results of Table: 2.7 shows that Revit package and MagiCAD software packages are applied for most of the projects. . If MagiCAD is integrated with Revit model, it is able to provide significant features for the model. that MagiCAD MEP software consists of different packages for different uses such as MagiCAD ventilation, piping, sprinkler designer, electrical, circuit designer, comfort & energy, room, supports & hangers.
Project Management	Autodesk Navisworks Products deliver project-review software for 3D coordination, 4D planning, near- photorealistic visualization, dynamic simulation, and more accurate analysis for integrate design data, analyse for coordination errors, evaluate construction schedules and communicate with all stakeholders
BIM Visualization	Solibri Model Viewer (SMV) and Navisworks Freedom can be used as most utilize BIM visualisation software tools.
Estimation tools	In order to achieve benefits from BIM technology, quantity surveyors (QS) will have to choose and use a BIM based estimating tool in BIM based projects. Most suitable BIM based estimating applications in the UK market are as follows; Solibri Model Checker v9.6, Autodesk QTO 2016. CostX 6, BIM Measure.

Civil and Infrastructure Engineering Tools	
AutoCAD Civil 3D	Civil 3D can provide effective design options and deliver high-quality documentations through the identification and analysis of the project performance. It is mostly used in infrastructure projects such as transportation, land development and water projects.
Tekla Civil	Tekla Civil is a well-known software solution for the civil engineering discipline to fulfil the needs of BIM. Also it enables implementation and distribution of up-to-date information between all operations in the project life cycle. Furthermore, it consist of powerful features to develop the information models, scheduling and planning. Moreover, it offers 3D imagining and can visualize civil projects using a combination of models.

5. WHAT IS THE PRELIMINARY STAGE FOR EFFECTIVE BIM IMPLEMENTATION IN SRI LANKA?

Today the construction industry is willing to provide value for money, and sustainable infrastructure. Also, this has resulted in a shift to BIM (Mihindu and Arayici, 2008). The clients can achieve better efficiency and significant cost savings through proper designing because this stage highly affects to later stages in construction projects, such as construction and operation of facilities. Therefore, the profession of architecture is the first step to adopt BIM (Coates *et al.,* 2010). Moreover, owners are starting to encourage architects and other design professionals, construction managers and construction companies to adopt BIM.

When it comes to the adoption of BIM the architectural firm will have to perform and incorporate the technology into the firm's business model. This will demand changes in project delivery methods and the composition of the firm's staff. Moreover, the productivity increment due to BIM will result in an increase in the attractiveness of the architects and other design professionals (Arayici *et al.,* 2011).

Historically, Sri Lankan architect firms used 2D CAD tool for two decades. Moreover, they used their own procedures, templates and traditional methods to perform their role. As Arayici *et al.* (2011) stated, 2D CAD options lead ineffective designs. There are two main factors should be examined when BIM adopting to a firm, such as purely install the BIM software in the firm structure or it could be runs on top of the existing 2D tools which are already installed. Further it stated that level of support and training should be provided by the software vendor. Software vendors such as ArchiCAD, Revit, Allplan, Vectorworks and Bentley Architecture can be mentioned as architectural software packages which are used in BIM.

To identify the most common BIM applications in the project, few case studies which were considered by many researchers. According to these findings it can be concluded that the most common software is Revit package. Therefore, due to the current use of the firms, can be going to Autodesk Revit Architecture.

5.1. CAD VS REVIT

Tobin (2015) expressed that when moving from AutoCAD to Revit, there are several questions should be asked themselves: Why we should move AutoCAD to Revit? And what the firm can gain due to this transition?, what is the reason for staying with software package which is similar to the AutoCAD environment/interface? What are the dissimilarities which are reflected from Revit models and CAD models, and due to these dissimilarities what are the profits can be accomplished? "Opportunity" can be answered to the first and second question, because Revit models can and will give more opportunities.

Further, as he stated answers for third and fourth questions, that Revit cannot be compared to AutoCAD. Users can not retreat on any bad habits that staff members may have committed over the years. The real difference of the Revit models and CAD models is, if the designer make any alteration to the element it automatically update throughout the building. Also, anytime and anywhere these alterations/changes can be done. When it considered to BIM following opportunities can be achieved.

- **Quality**

In the Revit models, any alterations/changes can be achieved during the Detail design and Construction Design phases. Further, this process is not hard, also this process help to increase the Quality of the product.

- **Productivity**

Designers can produce document while designing, this help to increase the productivity of the process. Further, if architect changed any element it is reflected to the MEP engineers. Moreover, schedules, drawings, coloured diagrams and take-off schedules can be produced and updated.

- **Cost**

Can be decrease the cost of the designing due to fewer resources. Further, this will help to decrease miscommunication problems.

- **Visualization**

Realistic photo renderings, animations, walkthroughs, 3D realistic models can be produced during any phases of the design process.

- **Facilities Management**

Apart from above benefits, the 3d models can be used to renovations, rectifications, maintenances, and space planning.

Further as stated by Aouad and Arayici (2010), there are some challenges that firms are going to run into when moving from AutoCAD to Revit Architecture. Assume the firm designer’s knowledge on the AutoCAD is very high. In such a situation, transition to Revit it is much easier. Because existing knowledge can be used to work with Revit. Further, it they do not have enough knowledge on the AutoCAD, then the road to the Revit is much tougher. Moreover, if the firm working with the multi disciplines parties (Inside or outside), Revit can be best solution for this situation. Apart from these situations, target firms must making an asset in Revit, with that comes time to setup and learn/train on the new system. Further, this should be aligned with the budget.

6. RESEARCH METHODOLOGY

The aim was to identify the competency of the professionals in zero level of the BIM and how much perform the BIM activities through the expected way of their practice. Due to broadness of the approach, target was narrowed to measure the competency level of the Architect professionals who are leading the Sri Lankan construction industry. Further, competency gap of the CAD software suit and BIM based Revit software package related to the Sri Lankan context which is performed by architects were recognized. Moreover, through the CAD, How far the task does is carried out without Revit. Also, get clarified that recognized task how much similar to the Revit environment. Thomas and Brubaker (2008) believed that qualitative methods are in conflict with qualitative approaches. Furthermore, they stated that the best method for the construction research is qualitative method. Therefore, best way is to conduct a qualitative approach. Therefore, considering these facts and according to the nature of the research the best way is the qualitative approach.

6.1. DATA COLLECTION

The challenge was to compare two different type modelling techniques with the BIM related activities which were performed by the Revit used architects. Hence, to perform this task, first identify the Architect activities on 3D modelling. Then through the desk study, get clarified that what are the capabilities on Revit and AutoCAD centred suit is used for perform this activities. Going through he lecturing on Autodesk University identified these competencies. Further using experts interviews from Sri Lankan architect professionals, clarified which tools used in the AutoCAD to fulfil identified activities. This helped to identified to what level of the competencies they have to go to the next level. As identified in the literature, the next level purposed as Revit package. If it not achieve in the AutoCAD, the next step was to identify the option that architect can go or already go. Apart from that get clarified “why it’s not practice by architect?”

Also, face to face interviews was conduct with Architects who are expert in their profession. The selecting conduct according to their role in the construction industry. First, focus on two academically experts and two industrial experts for collecting data. However, through this interview technique, it is possible to convey the background knowledge about the respondents in order to get clear answer about their practice on designing. Further, it help extract all the information which actually present. Due to the clarifying and elaborating capabilities of the semi structured techniques it can be used to data collect.

6.2. DATA ANALYSIS

According to the Westbrook (1994) identified that this content analyse process is the popular mechanism which is used among the professionals to analysis data. Also it give logical reliable implications from the given data. Moreover, Thomas and Brubaker (2008) stated that it entails searching through one or more communications to answer questions that researcher bring to the search. Code-based content analysis select to analyse based on the opinions gathered via the qualitative observational study and through interviews. NVivo (Version 11.0) used to cording and make straightforward the collected data for content analysis. Used windows based version to analyse the data.

7. ARCHITECTURAL ACTIVITIES ON SUCCESSFUL BIM MODEL DESIGNING

When considering to “BIM Implementation in Sri Lanka”, the first step is to encourage the architects to implement BIM. This is because architects who involve in the project prior to any involvement by any other professional. To accomplish this endeavour, the existing competency level of Architects on designing and how much those activities related to BIM must be identified. Anyhow through the opinions on current practices, identified the competency gap between the current practices on BIM modelling activities which are identified through the research findings. Apart from that if they not aware of BIM related activities, what they need to develop with their current competencies can be suggested. Hence, the purpose of the research was to identify the gap between their existing level of competency and desired level of competency, if a transition to BIM modelling was to be feasible.

Revit is a BIM software which can be considered as the most applied software package among various software packages. It has been proved through the literature review as well. Although there are lots of software packages used by Architects with supplementary packages, Revit is the most common and all-round software package among them. For effective implementation of BIM, development of the profession of architecture can be considered as first step in effective BIM transition process.

According to the analysis of the findings, one of the things that have to remember is that Revit is not AutoCAD and it does not work like AutoCAD. Revit is really a 3D design tool working completely with objects (e.g. walls, doors & windows). Working in Revit is more like building a building then drawing one. Look, the great thing about Revit is that all the objects work not the same as in AutoCAD. So if designer know how to place a wall in CAD, but you can’t place a wall in Revit. Because it use object oriented method. Fundamentals are just about the same, there are of course a few differences but can work through those fairly easily.

According to the desk study and expert survey findings, following conclusions can be arrived at.

Table 3: Summary of the Each Task Performed by Local Architects

Architect Activity	Conclusion on this Activity
Use of fundamental tools to make design elements of the project	Comparing both tools (Revit and CAD), both provide enough capabilities on 3D designing. But in the Sri Lankan Architects only used 2D drafting options for 2D drafting purposes. Such as lines, shapes, array, offsets, layers and text. Although there are 3D modelling options, any of these capabilities on 3D modelling are nor used. Users believe that using such kind of complex options wastes their time. Therefore, they may try other software such as Sketchup. Through the desk study it was identified that, way of handling those options was a little bit more complex than using Revit. Therefore, it can be concluded that users are still not aware of these tools.
Use Visualization techniques to make drawings look beautiful	Although, Revit provides Three different visualization techniques for visualize the model. CAD package users use hatches, different weighted lines, and colours for indicated materials and visualization purposes. When assigning materials on the elements, Revit provides very powerful techniques but local architect use different software packages for this such as V*ray, Lumion, Sketchup and 3Ds Max.*
Adding furniture, Components for the drawings	Revit provide families and components to fulfil these requirements. AutoCAD provide design center. But current practice is to design and use collected blocks for inserting components to the design. Although there are

Architect Activity	Conclusion on this Activity
	enough capabilities on the CAD, the CAD users following their own methods for perform this task.
Detailing and Documenting the Project Design.	In the AutoCAD, automatic generate system for tagging, detailing and scheduling is not provided. For example, view port besides using callout, adding text instead of using tags, creating detail lines besides model elements, importing AutoCAD schedules besides creating schedules in Revit, and so on. Architect used manual approaches to detailing.
Multi-user collaboration with project activities	Here, users are aware of this task. Used technique is “Xref”. It provides limited options compared to work-sharing option in Revit.
Evaluating Lighting and Daylighting performance of the modelling	In this task, current practitioners are not aware and not perform this task.
Use of Add-ins to create an efficient workflow and improve project documentation	In this task, current practitioners are not aware and not perform this task
Explore and manage point clouds to capture the existing condition of a building	In this task, current practitioners are not aware and not perform this task. Current practice is “*manual drafting*”.
Develop better and more efficient company Revit MEP template.	Here, also AutoCAD not provide a similar option related to templates. Current practice is using “*previous standard drawings”* and *“libraries*” which were developed as templates.
Produce rapid-energy models in Revit to gain renovation work	*In the AutoCAD, not provide capabilities to fulfil this task. Demolitions: Dash/ blue colour, New works: Red/ hatch cross, and existing works: Black double line* can be used to perform this task. Then give legend for the drawings.

8. CONCLUSIONS AND RECOMMENDATIONS

BIM is considered as a three dimensional (3-D) computer aided design software program; in reality BIM is a process improvement approach that influences data to analyse and predict results during different phases of the building life cycle. Through the literature review, BIM software packages which are used at the different stages by different professionals was explored. Moreover, through the case studies Revit can be exposed as the most commonly used software packages were identified.

When considering to “BIM Implementation in Sri Lanka”, the first step is to encourage the architects to implement BIM. This is because architects who involve in the project prior to any involvement by any other professional. To accomplish this endeavour, the existing competency level of Architects on designing and how much those activities related to BIM must be identified. Anyhow through the opinions on current practices, identified the competency gap between the current practices on BIM modelling activities which are identified through the desk study. Apart from that if they not aware of BIM related activities, what they need to develop with their current competencies can be suggested. Hence, the purpose of the research was to identify the gap between their existing level of competency and desired level of competency, if a transition to BIM modelling was to be feasible.

BIM is a technological and attainable concept, which has upgraded the construction industry into a more diligent industry. Due to constraints on the professional’s competencies on software it becomes a very hard goal for the Sri Lankan construction Industry. Therefore, starting with the architect profession it will become more achievable. Hence, identification of the current level of the knowledge and the development of the BIM software knowledge, finally the expected goal can be fulfilled. Using above summarized tasks, it showed that competency gap of the architects who following AutoCAD. This research emphasize that architects/designers are following most of the identified activities which are performed by the Revit user. But they are using few supplementary software packages for fulfil few of the activities (like Sketchup, 3D max). Although, there are enough capabilities on the CAD, architects do not practice them. Finally, the research study highlight that through the proper practice on identified options in the Revit and using current competencies, the architects can obtain better performance in the BIM process.

According to the summary, it can be concluded that Sri Lankan Architects much familiar few of the task. But, the handling/performing such activities differs quite a lot from they follow. If they are aware of these tasks then architects can practice it by following a diploma or using internet. Also, if the organization is willing to implement Revit in their organization. Then following methods can be offered,

- Establishment of training programme and lecture sessions for the architects

These training and lecture sessions could enable interaction with the staff to explore and capture the tacit requirements and needs, which could help for further the efficiency gains and improvements via Revit while increasing their current knowledge and skills in CAD. Also, identified competencies can be inculcated through this lecture series.

- Piloting Revit on the selected small projects such as housing projects.

This would be helpful for gradual increase in the use of Revit in the company. Furthermore, it would give an opportunity for training the staff and increasing their skills so that they may became proficient. It also provides the chance to observe what level of efficiency can be achieved via the Revit tool. The piloting projects helped to develop an understanding of what is needed for Revit modelling, which subsequently leads to improvements in how to sequence the steps in efficient BIM modelling through Revit.

9. REFERENCES

America, A.G.C., 2005. *The contractors guide to BIM*. Available from: http://iweb. agc. org/iweb/Purchase/ProductDetail.aspx. [Accessed 05 August 2016]

Aouad, G. and Arayici, Y., 2010. *Requirements engineering for computer integrated environments in construction*. New Jersey: John Wiley and Sons.

Aranda-Mena, G., Crawford, J., Chevez, A. and Froese, T., 2009. Building information modelling demystified: does it make business sense to adopt BIM?. *International Journal of managing projects in business*, 2(3), 419-434.

Arayici, Y., Kiviniemi, A.O., Coates, P., Koskela, L.J., Kagioglou, M., Usher, C. and O'Reilly, K., 2011. *BIM implementation and Adoption Process for an Architectural Practice*.

Autodesk (2013). *Autodesk AutoCAD Civil 3D 2014: Overview*. [online] Available from: https://www.youtube.com/watch?v=MB6mhwjpLSg [Accessed 12 Aug. 2016].

Autodesk (2016). *Revit*. [online] Available from: http://www.autodesk.co.uk/products/revit-family/case-studies/architectural-design [Accessed 22 Aug. 2016].

Benjaoran, V. and Bhokha, S., 2010. An integrated safety management with construction management using 4D CAD model. *Safety Science*, 48(3), 395-403.

Chelson, D.E., 2010. *The effects of building information modeling on construction site productivity* (Doctoral dissertation).

Coates, P., Arayici, Y., Koskela, K., Kagioglou, M., Usher, C. and O'Reilly, K., 2010. *The key performance indicators of the BIM implementation process.*

Cooperative Research Centre for Construction Innovation (Australia), 2009, *National guidelines for digital modelling*. Brisbane, Qld: Icon Net Pty. Ltd.

Deutsch, R., 2011. *BIM and integrated design: strategies for architectural practice*. John Wiley & Sons.

Gu, N. and London, K., 2010. Understanding and facilitating BIM adoption in the AEC industry. *Automation in construction*, 19(8), 988-999.

Haron, A.T., 2013. *Organisational readiness to implement building information modelling: A framework for design consultants in Malysia.* Doctoral dissertation, University of Salford.

Harris, J., 2010. Integration of BIM and business strategy. *McCormick School of Engineering and Applied Science*, Northwestern University, Evanston, IL.

Innovation, C.C., 2009. National guidelines for digital modelling. *Cooperative Research Centre for Construction Innovation, Brisbane, Australia.*

Jayasena, H.S. and Weddikkara, C., 2012. Building Information Modelling for Sri Lankan Construction Industry. In *Proceedings of World Construction Conference 2012: Global Challenges in Construction Industry*. 28-30 June 2012. Sri Lanka, 196-201.

Koskela, L.J., 2003, April. Theory and practice of lean construction: achievements and challenges. In *Proceedings of the 3rd Nordic Conference on Construction Economics & Organisation. Hansson, Bengt & Landin, Anne (eds). Lund University.*

Liker, J., 2004. *The Toyota way: 14 management principles from the world's greatest manufacturer.* McGraw-Hill.

Mihindu, S. and Arayici, Y., 2008, July. Digital construction through BIM systems will drive the re-engineering of construction business practices. In *Visualisation, 2008 International Conference,* 29-34. IEEE.

Olatunji, O.A., 2014. Views on building information modelling, procurement and contract management. *Proceedings of the Institution of Civil Engineers-Management, Procurement and Law,* 167(3), 117-126.

Omar, M.F., Nawi, M.N.M. and Nursal, A.T., 2014, January. Towards the significance of decision aid in Building Information Modeling (BIM) software selection process. *In E3S Web of Conferences* (3). EDP Sciences.

Peddinghaus, 2016, *Building Information Modeling, BIM, Tekla BIMsight, Tekla Structures, Interoperability, Tekla Open API* [online]. Available from: http://www.peddinghaus.com/tekla/bim-software/building-information-modeling/software-1/9002_tekla [Accessed 11 Jul. 2016].

Reddy, K.P., 2012. *BIM for building owners and developers: making a business case for using BIM on projects*. New Jersey: John Wiley & Sons.

Rogers, J., Chong, H.Y., Preece, C., Lim, C.C. and Jayasena, H.S., 2015. *BIM Development and Trends in Developing Countries: Case Studies.* Bentham Science Publishers.

Royal Institute of British Architects. (2012). Plan of Work | RIBA Bookshops. Available from http://www.ribabookshops.com/plan-of-work [Accessed 25 August 2016].

Sacks, R. and Barak, R., 2007. Impact of three-dimensional parametric modeling of buildings on productivity in structural engineering practice. *Automation in Construction*, 17(4), 439-449.

Sommerville, J. and Craig, N., 2006. *Implementing IT in construction.* New York: Routledge. Taylor and Francis Group.

Tobin, T., 2015. *The Time is Now - Switching from AutoCAD® Architecture to Revit®: The Right Attitude is Everything* [online]. Available from:http://au.autodesk.com/au-online/classes-on-demand/class-catalog/classes/year-2016/revit/ar17458 [Accessed 3 September 2016].

SPECIAL PURPOSE VEHICLE (SPV) MODEL FOR PRIVATE FINANCE INITIATIVES FOR LARGE SCALE INFRASTRUCTURE PROJECTS IN SRI LANKA

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ABSTRACT

Sri Lankan infrastructure development funding take up a good portion from the country annual budget. To cover up the cost of infrastructure projects, Sri Lanka use foreign funds and loans along with domestic earnings. Due to this process continuation for a long time, Sri Lanka has now ended up with dependencies to other countries. This research focus on studying Private Financing Initiatives (PFI) as an alternate solution for loans and insufficient Gross Domestic Product (GDP). Identifying available alternative methods, assessing suitability on private financing and developing a suitable Special Purpose Vehicle (SPV) model to suit Sri Lankan industry is the main objectives of this research. Moreover, what is PFI and how PFI was applied in other countries in their large-scale development projects, characteristics of PFI, how PFI can be attached with SPVs, what is an SPV have also studied using the available literature. In order to identify a suitable SPV in a PFI agreement, different types of SPV models has being compared. Further reasons for failure and rare existence of PFI in Sri Lanka, how PFI can be adopted to Sri Lanka, success factors, suitability of PFI and SPV, if a SPV is adopting to Sri Lanka how its relationships to be formed was identified by carrying out in-depth interviews. As conclusion, factors related to making a trend in PFI for project funding in Sri Lanka, government contribution in such projects and the need of change in government policies to bring up PFI contracts with a SPV, providing solutions for resisting PFI and leads to a successful adoption of PFI has being discussed.

Keywords: *Large Scale Infrastructure; PFI; Project Financing; Special Purpose Vehicle.*

1. INTRODUCTION

Sri Lanka is now taken up on a clear lead of infrastructure development by initiating mega scale projects in port expansion, toll roads, mega city development, Airport expansion etc. With the advancement of technology and the increment in population, complex public needs, the depth and scope of projects have being raised in multiple times. According to Agarwal *et al.*, (2011) “Infrastructure projects are complex, capital intensive, having long gestation period and involve multiple risks to the project participants”. In order to cope up those mentioned facts, large amount of funds are required and in common practice using either foreign funds or Government funds the requirement is full filled.

Excessive straining of government funds has the potential of leading Sri Lanka or any country into a public and foreign debt crisis. For the past few years, Sri Lankan Development projects were funded via government or foreign funding. Due to the insufficient GDP and lined up debts to pay, need for alternative funding in mega scale projects is arising. The following research was carried out in order research available alternatives and particularly to study the suitability and adoptability of PFI as an alternative funding method.

The aim of this research is to develop a framework to achieve a customized SPV model suitable for Sri Lankan context in PFI.

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2. LITERATURE REVIEW

2.1. *FUNDING METHODS FOR LARGE SCALE INFRASTRUCTURE*

"With the current global financial crisis, governments are expanding investment in infrastructure projects as a source of fiscal stimulus, with the twin objectives of job creation and improving economic performance" (Brude and Makovsek, 2013). In order to expand the capacities of new developments, Governments are now giving opportunities to the third parties to fund for the projects so the private sector can use their potentials in the development of the country and the same time they can get back a secure return on investment. Any government raises funds for projects using government bonds and guarantees, taxation, borrowing or printing money. Over doing any of these methods can cause for an economic crisis in a country. Due to the fact it's important for a government to raise funds using alternatives in a way it will not be a burden on the public or the private sector (Gardner and Wright, 2013). The types of contracts which were developed to benefit those public private contracts were categorized under Public Private Partnering (PPP). Later on another type of PPP was introduced in United Kingdom (UK) Private Funding Initiatives (PFI) where "Private Finance Initiative offers an alternative to the conventional procurement of public service infrastructure contracts" (Li *et al.,* 2005).

2.2. *SRI LANKAN PRACTICE*

For the year 2015 around 1051 development projects have been implemented. Out of this 306 projects were considered as large scale projects which have an estimated budget over Rs. 500 million (Department of Project Management and Monitoring, 2016). The major portion of these large projects were funded by the Sri Lankan government with the aid of foreign borrowings and funds. Even though government make an effort to bear all the expenses of these projects using borrowings or treasury bills, due to the war crisis in the country 8 years ago made a negative impact on the economy, where as a country Sri Lanka still in attempt of recovering from an excess amount of foreign debts collected among that period.

With the existing funding procedure in Sri Lanka according to Department of Project Management and Monitoring (2016) among the large-scale traditional project category, 14 projects have reported project cost overruns than the estimations, 44 projects have reported a time overrun and in addition around 10 projects have delayed in the project implementation cycle and are underperforming due to various reasons. "Weak contract management, lack of co-ordination among relevant stakeholders, poor project management capacity in project management units" were few that could be identified (Department of Project Management and Monitoring, 2016). Furthermore, according to that report during the year 2015, 10 large scale projects have come across scope changes due to various reasons such as policy decisions, technical issues and unattended bottlenecks.

Similar situations has occurred in some other countries where the public infrastructure project financing lead to failure has raisen the necessity to adopt alternative private funding. UK, Malaysia, Sweden, Japan and United States of America are few countries who successfully developed alternatives (Yamaguchi *et al.,* 2001). As in Sri Lanka the productivity of the system can be increased if the government can go for alternative funding and procurement method rather sticking into government funding traditional procurement method.

2.3. *WHAT IS PFI?*

"Private financing is a promised way to provide infrastructure without increasing the public sector borrowing requirement (PSBR)" (Hodge and Greve, 2009).

The Private Finance Initiative was initiated in UK. It is a type of PPP where the contribution of many private parties and the government to seek and to combine the advantages of competitive tender, flexible negotiation, and transfer risk away from the public sector (Bing *et al.,* 2005).

"Private Finance Initiative (PFI) offers an alternative to the conventional procurement of public service infrastructure" (Zainon *et al.,* 2012). Rather holding into old procurement method, in Sri Lanka medium and small scale projects were opened up to PPP and PFI (Yatanwala and Jayasena, 2009). Even though it's manageable with traditional lump sum contract for medium and small scale, when the project scope get larger and when the public funding is insufficient PFI is one out of the best options because, "at its best, private investment can save the public money and improve services in the long run" (DiNapoli, 2013).

2.4. CHARACTERISTICS, USE, SUITABILITY AND ADAPTABILITY OF PFI

PFI has the characteristics of bearing the upfront cost of a project, risk sharing, multi-party collaboration, long term build and operation contracts with expertise and pioneer stakeholders in the industry, adaptability to large scale projects, cost saving opportunities and consideration of Value for Money concept. According to a study conducted in UK the researchers have received a good feedback form sampled project survey conducted for target group of projects which were in design and operational phase and according to the following source they have received 53% of highest ratings and no negative feedbacks have being received, this data collection has being done in 2003 in terms of successability of PFI" (Beckett, et al., 2009).

PFI has the easy adaptability to any scale of project. It has being adapted in many sectors different scale projects in many countries. For example in military sector countries like USA are initiating private funding initiatives for their purchasing and maintenance of combat airplanes etc. (Bradford, 2001).

There are three types of PFI can be identified in the practice,

i. Free standing projects
ii. Joint venture
iii. Service sold to the public sector (Alen, 2001).

2.5. SUCCESS FACTORS OF PFI

In the eyes of a private investor the factors that affect his decision for an investment is the Return on Investment (ROI) and the associated risk (Chavers *et al.,* 2015). If the government can initiate a potential financial return on infrastructure development projects in a secure environment for the investment raising funds for public service development won't be much challenging (Ali, 2008). "What transforms a desirable project on a government wish list to an attractive investment opportunity in the eyes of a potential private sector partner" (Farquharson *et al.,* 2011).

At the end of the review, success factor of a PFI project were identified as following,

- Defining a commercial value and defining potential ROI for infrastructure projects
- Securing a low risk or a risk sharing environment for investors
- Flexible Government policies towards establishment of SPV and new PFI firms
- Accurate output specification
- Negotiation with willing private investors
- Skilled contract management (Chan *et al.,* 2009).
- Well-structured SPV
- Right collaboration of stakeholders
- Political stability of the country (Chan *et al.,* 2009).
- Political influence on a PFI project and investors
- An experienced project management team and team leaders
- Striving a balance between traditional firms and new PFI firms
- Encouraging entrepreneurs for PFI projects by open opportunities and flexible agreements
- Knowledge distribution in the industry about PFI
- Construction program of a PFI consists of a flexible schedule
- Good communication between stakeholders

2.6. USE OF SPV IN PFI AND POTENTIAL BENEFITS OF A WELL-DESIGNED PFI WITH AN IDEAL SPV MODEL

When a PFI contract is initiated, it comprises of three parties, the awarding authority, the special purpose vehicle (SPV) and third party funders (Dixon *et al.,* 2005). Unlike in PPP in PFI, the use of a SPV is common. According to explanations in literature SPV and Special Purpose Entities (SPE) are defined as follows, "Special Purpose Vehicle (SPV) created by the equity partners to fund the project" (Akbiyikli *et al.,* 2006). "A delegating entity typically commits to buying a future flow of goods or services from a project company or SPE, with which it enters into a long-term contract" is known as a SPV.

Traditional infrastructure projects will be holding higher risk to both ends of a contract, the larger the scope gets the more the risk intense, contrary to traditional method, the risk that a SPV or a SPE creates for every contract end is comparatively little. The use of SPV was recognized in USA after failing many PPP projects due to poor negotiation and insolvency of stakeholders and costly design changes, or dramatic declines in the number of users (DiNapoli, 2013). SPV can withstand the insolvency and manage better coordination between parties if the structure of the SPV is designed properly.

SPVs' will be allowing accommodating different parties in one platform while providing a secure environment in financial and legal terms. Further SPV have the potential to get "characteristic advantages of free markets, increased competition, more accurate and sensitive pricing, expanded financing options, and timely response to demand, in the provision of public goods" (DiNapoli, 2013). SPV's can preserve a good relationship between every party involved through a well-structured communication web, which will reduce mistakes, miscommunication, flexible working environment and established contractual relationships between parties for less disputes. Further SPV will be allowing to recognize the interests of different stakeholders, and "coordinating the development and operation of a particular project with the needs of larger systems and adjacent communities" (DiNapoli, 2013). SPV has an adaptability towards its imposes on risk management, and the costs of financing and the ability to reduce life time costing since an infrastructure project contract hold the operation and maintenance part of work (Chan *et al.*, 2009). Government has the benefit of using SPVs to fast track immediate development plans without going through all the government officials and agencies and SPVs relief private companies from nonperforming idling assets (Pasadilla, 2005).

2.7. CHARACTERISTICS OF POTENTIAL STAKEHOLDERS

The parties involved in a SPV have to have unique characteristics to survive in a multiple party association. Since these formed SPVs' may last long for 30-40 years it is critical to identify the potentials and required characteristics of the stakeholders for a successful PFI project with a well-managed SPV.

The mother company should have the potential to set off some of their resources for management of the SPV. With this separation SPV has to be responsible on managing its' funds, decisions and risk capital as an independent organization. Even though the risk involved with SPV can be comparatively low, the stakeholders should be readily available for risk management (Gorton and Souleles, 2007). Ability to communicate with multiple stakeholders, good negotiation skills, good reputation, previous experience in similar projects and previous experience in PFI type projects are added advantages.

Work experience with government, established organization structure and ability in good project management are another significant characteristic of a SPV stakeholder. This mentioned type potential stakeholders are readily available in Sri Lanka, who are currently not involved in construction sector or not with any announced plans to form partnerships with government.

2.8. ADAPTING SUITABLE SPV FOR SRI LANKAN CONTEXT

"An SPV may be structured in different ways, depending on what the originator is trying to achieve through the vehicle and depending on where it is originated geographically" (Gosrani and Gray, 2011).

When choosing the team for a SPV the according to Edkins and Smith (2006) from the early stage itself the structure of the SPV to be planned and it's better to make the possible parties involved from the initiation for higher performance.

2.9. REVIEW OF EXISTING SPV MODELS

- *Model one*

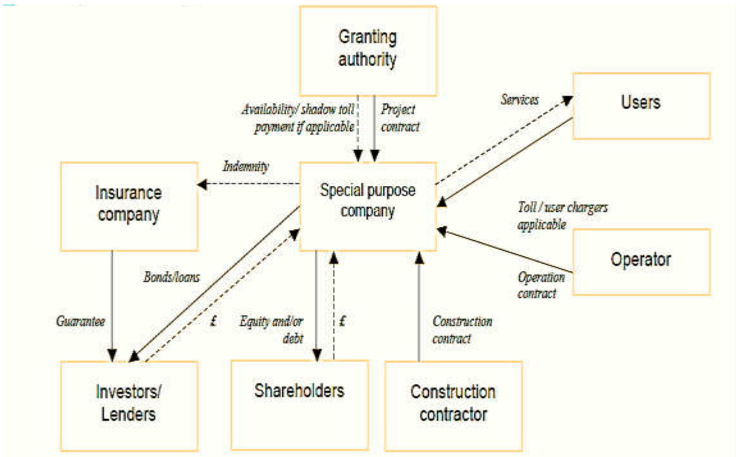

Figure 1: UK PFI Arrangement

(Source: HM Treasury, 2003)

The characteristics that can point out of these two models are,

- Government has a bond with the SPV company and the SPV company manage the bonds with other involved stakeholders.
- Since the SPV's virtually do not have an operation body this SPV company responsibility falls in to the main construction contractors' hand and after handing over it'll be passed into operation and maintenance contractor.

- *Model two*

In this type the PFI contract will be only exist between the SPV contractor and the government as in Figure 2 and the main financial institutes will be having a direct link with government. Other than the senior lender there will be secondary lenders funding the project linked to the SPV with shareholder agreements and the senior lender lends money in a loan basis so the main contractor can balance it by the time of the return on investment.

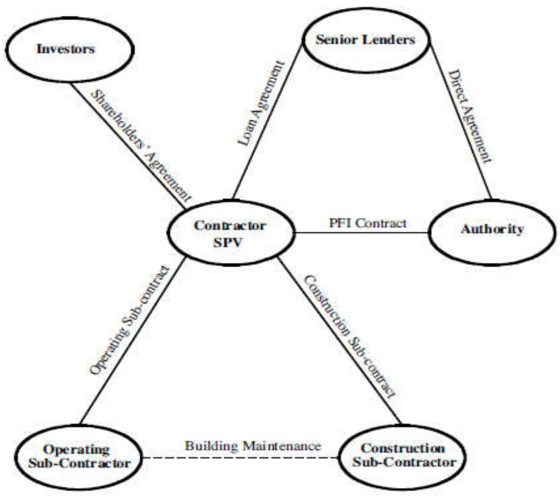

Figure 2: Lender Authority Direct Agreement Arrangement

(Source: Lemos *et al.*, 2003)

- *Model three*

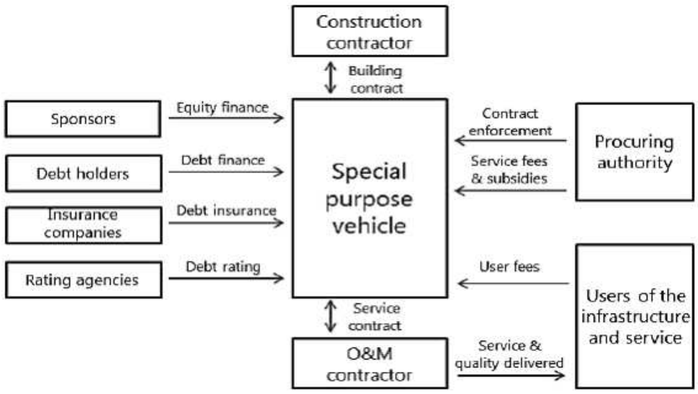

Figure 3: Web of Contracts in SPV

Source: Ehlers, 2014

In this model (refer Figure 3) each party holds a financial responsibility or a share of the SPV with established contractual relationships. So the risk and the cash flow is distributed among everybody.

- *Model Four*

In the following structure (refer Figure 4) “the underlying assets or loans are purchased by the SPV, then grouped into tranches (portions) and sold to meet the credit risk preferences of a wide range of investors” (Gorton and Souleles, 2007).

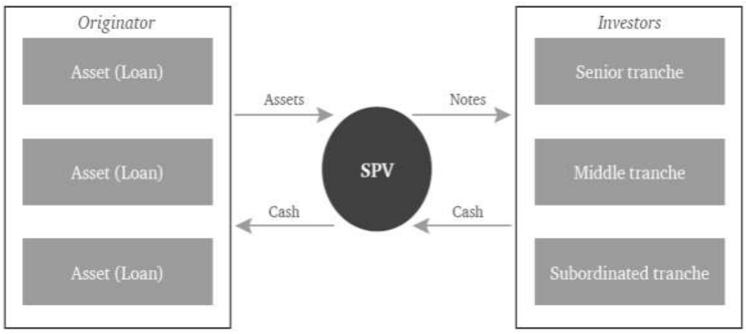

Figure 4: Securitiation Model

(Source: Gosrani and Gray, 2011)

2.10. PRE-DEVELOPED MODEL

Figure 5 shows the possible stakeholder relationships that could be form in between the possible potential stakeholders as a combination of all the above studied models. Further, in Figure 5 two-way relationships are not defined and it was intended to confirm how the relationships are to be formed during the interview phase.

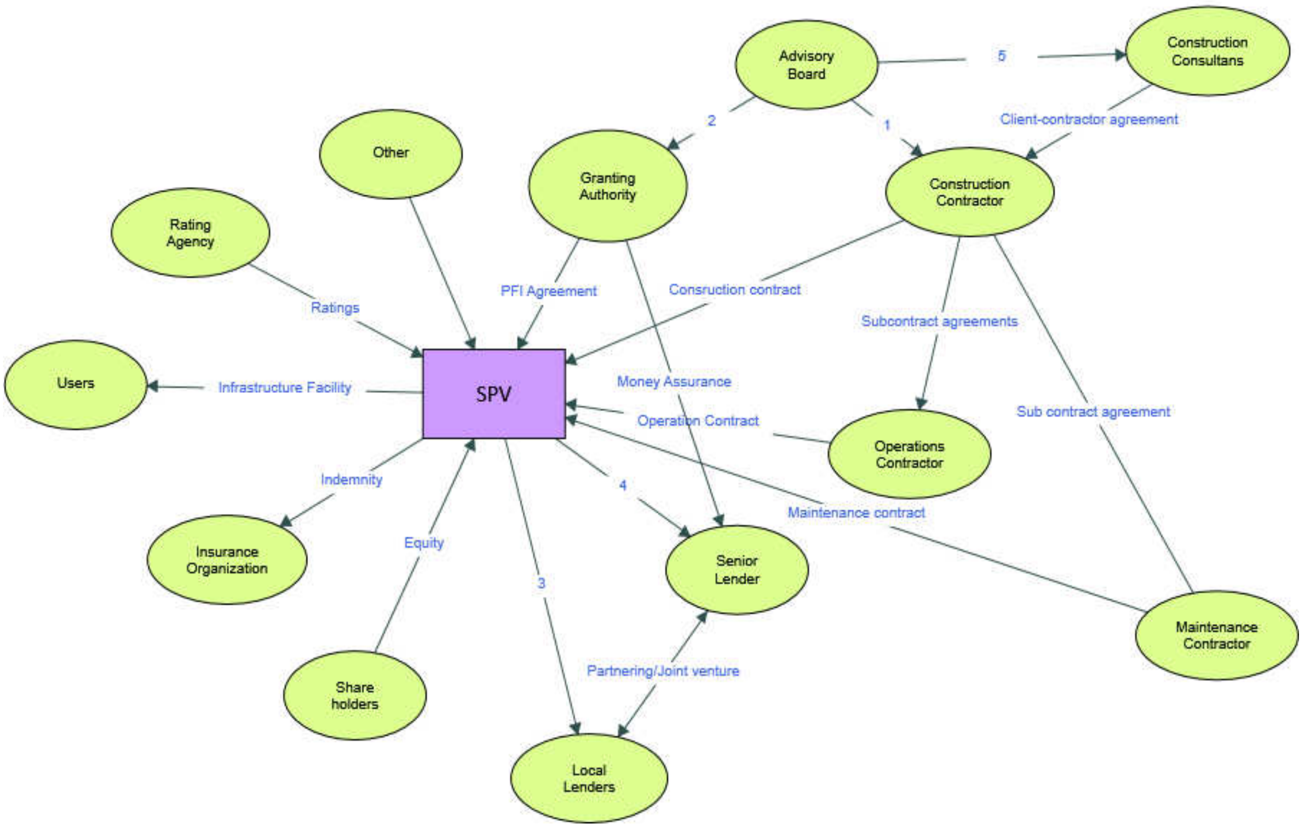

Figure 5: Potential Relationships and Stakeholders of SPV

3. RESEARCH METHODOLOGY

Previously in section 2, it was described the related studies carried out related to this topic and using them as an outline to data collection the salient points of this case were lined up, the methodology was identified in regards to the collected points. The method to carry out this research mainly focused on the data collection with regard to the identified model testing and collecting the industry feedback to identify the success factors of the model.

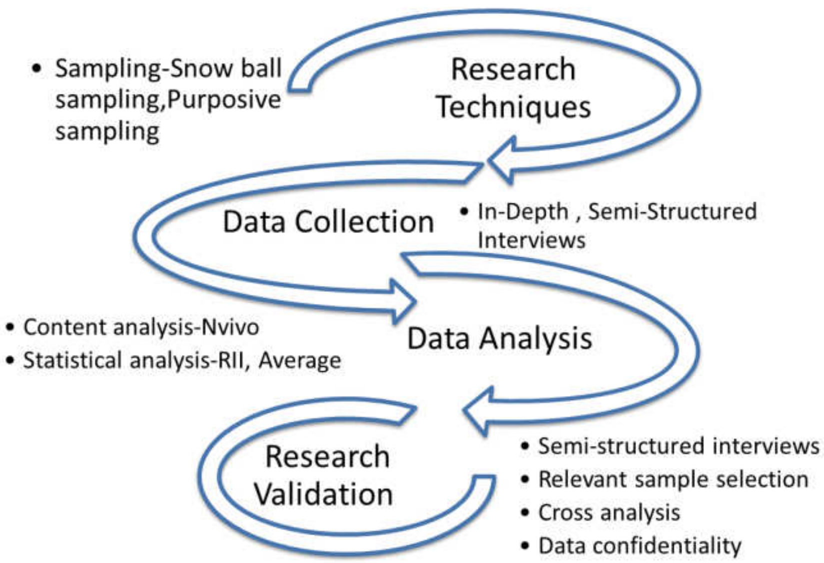

Figure 6: Research Methodology

4. DATA COLLECTION AND ANALYSIS

For the above research as mentioned in the methodology chapter, a field survey was done using in depth interviews for a randomly picked sample considering experts attached to mega scale development projects carried out and on-going using snowball technique. For this research, 13 interviews were carried out among relevant population. Out of the 13 respondents, two interviewees were from Granting Authorities, three from Project consultancy, three from local Contractors, one foreign contractor, one from senior lender organization, one local lender, one advisory board member and one maintenance and operation contractor. Out of all 13 interviewees three had experience of PFI and eight other interviewee's have being involved in PPP projects and two have had no previous experience in PPP or PFI but have being involved in large scale infrastructure projects.

4.1. REASONS FOR NEED FOR ALTERNATIVES IN SRI LANKA

During the research first phase in identification of the research problem, it was identified that government is burdened with debts where the government is in verge of finding alternatives to fund for the rising infrastructure need in the country. As planned in data collection phase to check the accuracy of this situation and the suitability of deviating from direct funding to alternate funding methods were examined.

Out of 13 interviewees 12 agreed the reason to go for and alternative project financing method was because the Sri Lankan current insufficient GDP to fund large scale projects. More over at the moment government is having difficulties in allocating money for bigger projects from the budget due to lack of upfront money. According to some interviewees the need of alternatives arise to ease the current debt burden using self-sufficient projects. Even though all experts agreed for the need of alternative funding methods the question "why as a country alternative funding is not so popular among public infrastructure" was asked. According to them, the reasons for the resistance to adopt alternative funding methods were as below,

- Political instability
- Public resistance
- No investment friendly government policies
- Lack of knowledge
- Government corruption and bad political decisions
- Government policies

Almost all the interviewees agreed that the reasons for this negative tendency towards alternative funding methods have arisen due to Sri Lanka's instable political and policy conditions. Another reason for the resistance for alternative funding methods according to interviewees 6, 8 and 5 is the lack of practice and lack of knowledge among the public. More over government corruption and bad political decisions drive away the attraction of other possible parties like multi-national companies coming to Sri Lanka.

4.2. SUCCESS FACTORS OF PFI

In order to find ways to adopt PFI to Sri Lanka the factors that can successfully support the process were identified, through interviewees respond the Relative Important Index (RII) were calculated and the factors were ranked (refer Table 1).

Table 1: Success Factors of PFI

Item No	Factor	RII	Rank
1	Having good commercial value for the project	3.54	2
2	Consistent government policies	3.92	1
3	Well- structured SPV	2.23	5
4	Right collaboration of stakeholders	2.46	4
5	Political stability of the country	2.85	3

The importance of consisting government policies was highlighted in the data collection. Having a good commercial value for the project was identified as the second important success factor for PFI contracts in Sri Lanka and further, the political stability of the country for the third factor and SPV arrangement related factors as least impacting factor out of these factors.

4.3. FAILURE FACTORS OF PFI IN SRI LANKA

Table 2: Failure Factors

Item No.	Factor	RII	Rank
1	Political instability	4.23	1
2	Resource constraints	2.92	2
3	Weak Economy	2.54	4
4	High Risk	2.77	3
5	Lack of knowledge and practice	2.54	4

Acording to Table 2, the results revealed that the main reason for the PFI resistance in Sri Lanka was due to the Sri Lankan political instability and lack of policy consistency. Then resource constraints like high technology, high skilled labour, funds, expert professionals is the second negative factor that affected Sri Lanka in adopting PFI. High risk associated with PFI was ranked as the thirdly impacted failure factor for PFI and weak economy and lack of knowledge and practice of this method had being the least effecting factor out of these five failure factors that were identified in literature.

4.4. FORMATION OF SPV

1. Granting authority - SPV

In the model developed the PFI contract to be exists between the granting authority and the SPV.

2. Insurance organisation - SPV

There were two options of insurance identified for this model in the literature review; first option is to insure every stakeholder and secondary relationships of the SPV through the SPV. Second option is to insure just main stakeholders such as main contractor, advisory board and the senior lender. Out of these two types, 11 respondents agreed that the SPV itself to be insured along with all secondary parties.

3. Senior lender - Granting authority

In this relationship three concerns were raised,

- Money assurance for the senior lender- Nine respondents agreed that money assurance between the granting authority and senior lender is not necessary.
- Direct connection between the granting authority and lender effect the transparency- Eight interviewees out of Eleven agreed that a connection between the granting authority and senior lender would affect the transparency in a negative way.
- No direct links between but authorized links for communication- when the majority agreed to not to have a direct link between these two parties it was again mentioned having an authorized link to communicate and to maintain a certain relationship between is important for the success of the SPV

4. Senior lender-local lender

It was preferred by the local lender to work under the senior lender since local banks cannot invest in projects according to country law in Sri Lanka.

5. Advisory board-SPV-Client

Advisory board was preferred to be directly attached to the SPV and five respondents agreed to have the clients advisory board to be novated to the SPV. Regarding the construction consultants, it was suggested by the respondents to have a link between advisors and consultants for a better communication.

6. Rating agency

There was no prominent need of having a rating agency attached in Sri Lankan context

7. Financial structure

Debt-equity balanced financial structure was majority agreement on the SPV financial structure and the percentages will be varied upon the type of the project and according to the agreed parties. As an extended proposal all the stakeholders or a few major stakeholders can be shareholders of the SPV.

8. Main contractor-Operation and maintenance contractor

Since this research was on mega scale infrastructure interviewees suggested that having operation and maintenance contractors directly attached to the SPV

9. User-SPV

Regarding the decision of the user fee, best counsel was that the granting authority should make the decision in the project feasibility stage.

Further as suggested by respondents about the potential stakeholders to take part in the SPV were environment organizations, international and local political representation or counsellors, public and instead of the granting authority government was nominated.

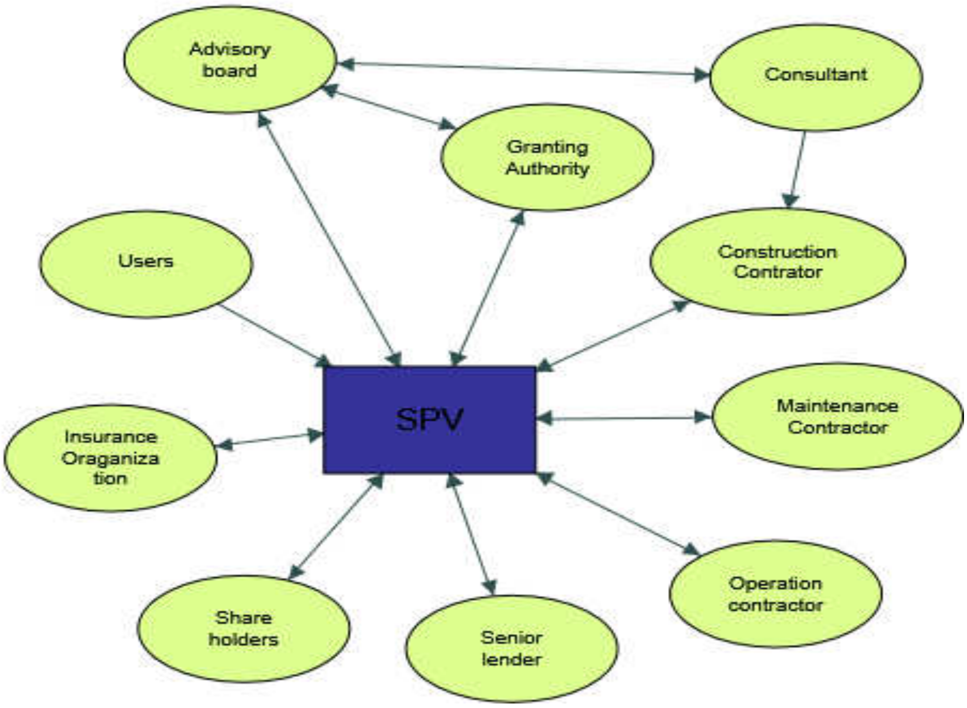

Figure 7: Identified Direct Links of the Model

4.5. SRI LANKAN PRIVATE SECTOR POTENTIAL TO JOIN PFI

Responses about the Sri Lankan private sector potential to take over or make joint agreements in investing Sri Lankan large-scale infrastructure projects were as ensuing.

Accordance to collected data, 76.9% agreed that Sri Lankan industry has the potential to go hand in hand in public sector investments. “Sri Lankan private sector needs more competition to grow, at the moment even they have the potential they are limit to medium and small scale”. Along with this agreement, they also mentioned that Sri Lankan private sector is small and limited in scope where they need to grow further to get the control over large-scale projects.

4.6. *Characteristics of Potential Private Sector Stakeholders for a SPV*

For a stable and a strong SPV the following factors were expected from firms according to the experts comment,

- Risk management skills
- Long term investment plan
- Potential funding
- Established organization structure

The importance of above factors were specified as following. “Doing joint business with Sri Lankan government itself is a risk. Unless the firms who are willing to invest in those SPVs have long term investment plans with adequate funding to maintain their current cash flow as well as to grow in technology and have a stable established organization structure it’ll be a critical decision in investing in large scale infrastructure projects”.

5. Conclusions and Recommendation

As a country, Sri Lanka do recognize the need of considering alternative project financing methods for large scale infrastructure projects according to above chapter, due to the reasons of insufficient GDP in the country, payable loan burden upon the country and constraints in providing upfront money to a project.

Up to now PFI has failed as an alternative method in Sri Lanka due to facts that Sri Lankan political and policy instability, resource constraints and lack of knowledge and practice in PFI. To adopt PFI to Sri Lankan context, it was concluded to have following factors, good commercial value to the project, government policy consistency, politically stable country environment, according to Table 1.

The SPV concept to adopt in large-scale infrastructure projects was analysed in the data collection phase. It was identified the resistance towards SPV has being mainly due to the lack of policy consistency, and the external influences subjected upon a SPV. It was further identified if the SPV is formed in a way that third party influences and continuation of the SPV is assured through policies the trend for SPVs’ will be increased.

5.1. *Recommendations for the Government*

Upon the success of a PFI contract collaborated with a SPV, the government influence is a critical factor. In related to Sri Lankan context the reasons behind failure and resistance towards adopting PFI are easily correctable if the government see PFI as a potential project financing method. As recommendation to the government for successful PFI project the most effective step that can be taken is, setting up consistent policies related to PFI, giving tax concessions and investments opportunities in government development projects to the private sector. Moreover, the private sector looks for an assurance of the project continuation upon the government instability for project consistency and if the government can initiate projects based upon real public need rather using projects in gaining political advance the trust and involvement of the private sector is expected to increase. As the government, initiation and encouragement to practice PFI should be from their side. Other than to policy development, practicing productivity in government organization, minimizing corruption, open door policy towards private small-scale investors, identification and development of new infrastructure projects and developing coordination between government authorities will be a good way of developing private sector interest in government investments according to the feedback received from the experts.

5.2. *Recommendations for Potential Stakeholders*

Any private sector firm who are interested in investing on a PFI project should consider the following factors according to conclusions made with collected data. Projects with a viable financial structure or with government gap funding are recommended for PFI type contracts.

- Ensure your organization goals and objectives are in line with project details. Do a risk analysis before entering into a PFI contract and asses the risk bearing capacity of your organization
- Consider the project viability, payback period and the type of agreement that is formed with the SPV

- Analyse the exit procedures and in case of insolvency what kind of security is provided for the stakeholders

5.3. FACTORS TO BE CONSIDERED BEFORE ESTABLISHING A SPV AND CHARACTERISTICS OF POTENTIAL STAKEHOLDERS

It's recommended for the parties that are entering in to a SPV to consider the following facts. Structure of the SPV, established connections within the SPV stakeholders, check organization capabilities in long term investments, potential funding to invest in a SPV, established organization structure, analyse the skills of the SPV management team.

The sustainability of a mother company should not be risked upon the SPV when entering a PFI contract. Before entering a SPV the company should have potential funding to manage organizational expenses in the project initiation phase in case of joint venture PFI projects and shareholder type PFI agreements. The management team of the SPV should be selected with consideration for their skills and qualifications because SPV management plays a vital role in its success. The management team should have trustworthy, unbiased, honest team players ensuring equal treatment to all parties and dealing with the stakeholders in a genuine way.

Characteristics of potential stakeholders to be a part of an SPV are recommended as, established organization structure with long term organizational goals, previous experience in related projects, working with government authorities, working in joint ventures or partnering, interest in serving public. This becomes a necessity due to the share of risk in an SPV for a stakeholder and its challenging nature. Previous experience in PPP projects, large-scale projects, and government projects will give the beneficial in spontaneous and good decision-making and easy dealing with other involved parties and challenges. Proposed model for the SPV-Final development

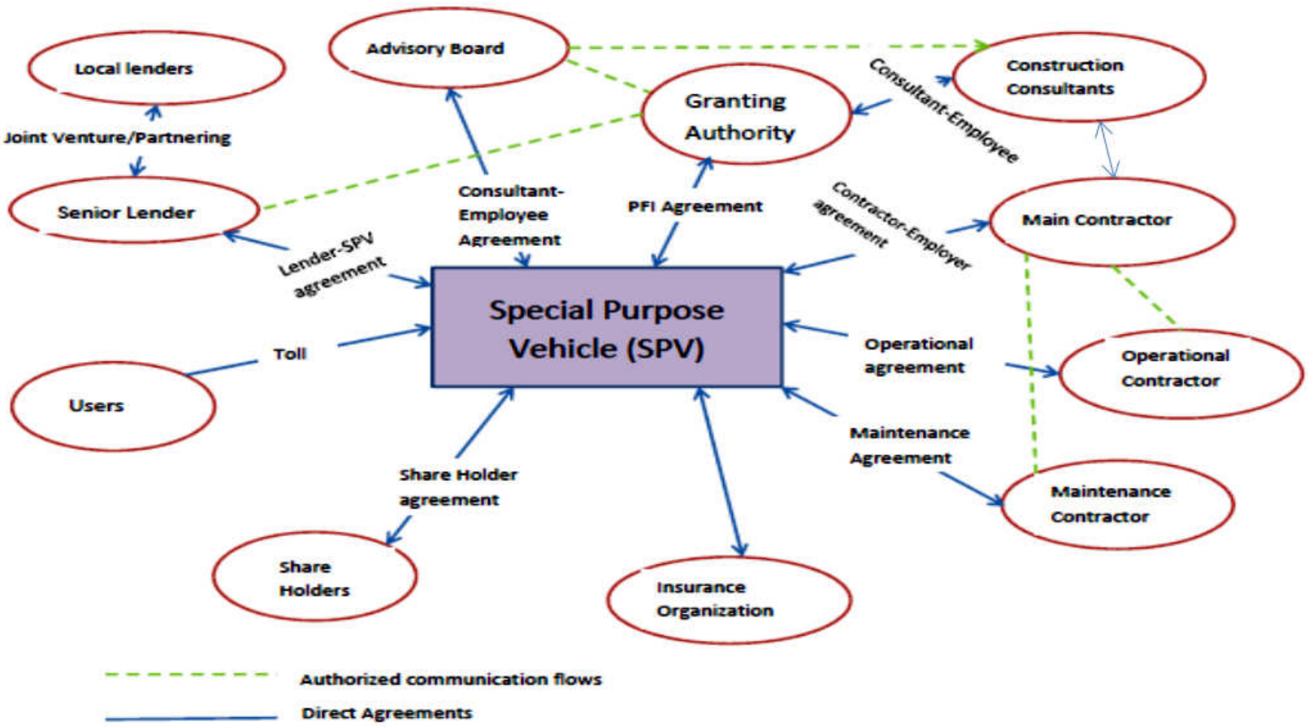

Figure 8: Proposed SPV Model

Figure 8 shows the proposed SPV model using the collected information in the data collection and analysis phase. According to the paragraph formation of SPV, the above relationships were identified. During the data collection the contractual relationships and importance of identifying and differentiating communication links were highlighted and they are included in the above model. Further, type of agreement that will be established in between the SPV and the stakeholders are mentioned on the direction arrows of the above diagram. Further proposing this model was the objective of this research which is a proposed model of SPV that can be applied in Sri Lankan context along with PFI agreements.

6. REFERENCES

Agrawal, R., Gupta, A., and Gupta, M.C., 2011.Financing of PPP Infrastructure Projects in India: Constraints and Recommendations. *The IUP Journal of Infrastructure*, 9(1), 52-55.

Akbiyikli, R., Eaton, D., and Turner, A., 2006. Project finance and the Private Funding Initiatives (PFI). *International Investor Journal*, 4-68.

Ali, A. M., 2008. *Private Finance Initiatives as a part of the 9th Malaysian plan.* Kuala Lumpur: Azmi and Associates.

Allen, G., 2001, December. *The Private Finance Initiative (PFI).* [Online] House of commons library, economic policy and statistics section. Available from: http://www.parliament.uk/ [Accessed 4 August 2016].

Beckett, M., Drazin, S., Finlay, D., Smith, H., Martin, N., and Neathey, R., 2009. *Performance of PFI construction*. [Online] National Audit Office. Available from: https://www.nao.org.uk/wp-content/uploads/2009/10/2009_performance_pfi_construction.pdf [Accessed 30 August 2016].

Bing, L., Akintoye, A., Edwards, P. J., and Hardcastle, C., 2005. The allocation of risk in PPP/PFI construction projects in the UK. *International Journal of Project Management,* (25), 3-11.

Bradford, M., 2001. The British Model of Private Finance Initiative and Public-Private Partnership Ten Years Later: Toward International Extension in the Defense Sector? *The Journal of Structured and Project Finance*, 1-11.

Brude, F.B., and Makovsek, D., 2013. *Construction Risk in Infrastructure Project Finance*. France: EDHEC-Risk Institute.

Chavers, K., Synnott, A., Parkes, M., and Pilibossian, A., 2015. *Infrastructure Investment: Bridging the Gap Between Public and Investor Needs*. BlackRock, 17-20.

Chan, C., Forwood, D., Roper, H., and Sayers, C., 2009. *Public Infrastructure Financing — An International Perspective.* Productivity Commission Staff Working Paper, 10-65.

Department of Project Management and Monitoring. 2016. *Development Performance - Mid Year Review 2015*. [Online] Integrated National Development Information System: Available from: http://www.pmm.gov.lk/resources/Development_Performance_YearEnd_2015.pdf [Accessed 31 August 2016]

DiNapoli, T., 2013. *Private Financing of Public Infrastructure: Risks and Options for New York State*. New York: New York State Comptroller.

Dixon, T., Pottinger, G., and Jordan, A., 2005. Lessons from the private finance initiative in the UK Benefits, problems and critical success factors. *Journal of Property Investment and Finance,* 23(5), 412-423.

Edkins, A., and Smyth, H., 2006. Contractual Management in PPP Projects: Evaluation of Legal versus Relational Contracting for Service Delivery. *Journal of Professional Issues in Engineering Education and Practice*, 132(1), 82-93.

Ehlers, T., 2014. *Understanding the challenges for infrastructure finance.* BIS Working Papers, 2-9.

Gardner, D., and Wright, J. 2013. *Project Finance*. USA: HSBC.

Gorton, G.B., and Souleles, N.S. 2007. *Special Purpose Vehicles and Securitization*. Electronic Journal, 5(21), 22-23.

Gosrani, N., and Gray, A. 2011. *Creating an understanding of Special Purpose Vehicles.* The next chapter.

HM Treasury.2003. *PFI: meeting the investment challenge.* London: The Stationery Office.

Hodge, G. A., and Greve, C. 2009, March. PPPs: The Passage Of Time Permits a Sober Reflection. *Economic Affairs*, 29 (1), 33-39.

Lemos, T. D., Betts, M., Eaton, D., and Almeida, L., 2003. The Nature of PFI. *The Journal of Structured Finance (Spring)*, 28-38.

Li, B., Akintoye, A., Edwards, P. J., and Hardcastle, C., 2005. Perceptions of positive and negative factors influencing the attractiveness of PPP PFI procurement for construction projects in the UK: Findings from a questionnaire survey. *Engineering, Construction and Architectural Management*, 12(2), 125-148.

Gardner, D., and Wright, J.,2013. Project Finance. HSBC USA. PPP/PFI procurement for construction projects in the UK. Engineering. *Construction and Architectural Management*, 12(2), 125-148.

Pasadilla, G. O., 2005. *Special Purpose Vehicles and Insolvency Reforms in the Philippines*. Makati City: Philippine Institute for Development Studies.

Yamaguchi, H., Uher, T., and Runeson, G. 2001. Risk Allocation in PFI Projects. *17th Annual ARCOM Conference.* Manchester: Association of Researchers in Construction Management. 32-87.

Yatanwala, Y., Jayasena. S., 2009. *Failure of Applying PFI in Colombo Katunayake.* [Online] Available from: https://www.irbnet.de/daten/iconda/CIB11521.pdf [Accessed 20 August 2016]

Zainon, N., Lou, E., and Suhaimi, M., 2012. How it actually works - Private Finance Initiative (PFI). *Wulfania Journal*, 1-7.

STRATEGIES TO IMPROVE THE PRODUCTIVITY OF SITE LEVEL BUILDING CONTRACTORS IN SRI LANKA

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ABSTRACT

The construction industry is widely recognised as a laggard in terms of productivity improvement. Site level construction productivity is a major influential factor to reduce the overall productivity in the construction industry. The main reason behind this is the critical site level construction productivity problems faced by Sri Lankan contractors. Therefore, aim of the study is to identify the possible solutions to enhance the site level construction productivity of building contractors in Sri Lanka. Accordingly, a mixed approach was used for the research. Initially, an extensive literature review was carried out to identify the site level construction productivity influential factors which was followed by a preliminary survey to investigate the critical problems influencing the site level construction productivity of contractors in Sri Lanka. A questionnaire survey was carried out to identify the most critical site level problems faced by the building contractors in Sri Lanka. Finally, expert interviews were conducted to identify the possible solutions to enhance the site level construction productivity of building contractors. Findings revealed that the most critical site level problems include worker skills problems, worker motivation problems, unavailability of skilled labours, and material management problems on sites. Accordingly, introducing proper training programs, implementing incentive, rewards and appreciation schemes as per the workers' performance, training unskilled workers, educating site workers on proper usage of materials are the possible solutions for the identified four most critical problems.

Keywords: *Building Contractors; Construction Process; Construction Productivity.*

1. INTRODUCTION

Construction industry has become the world's largest and most challenging industry (Fulford and Standing, 2014). When considering the productivity of construction industry, contractors play a vital role through their direct involvement during the construction work and the contractors were identified as the most influential factor for the construction productivity in a country (Navaratna and Jayawardane, 2007). Further, contractors' productivity can directly influence to the overall economy due to the number of processes and activities involved in the building construction industry (Navaratna and Jayawardane, 2007). Therefore, giving considerable effort to improve the building contractors' site level construction productivity is an important phenomenon, however this has become challengeable due to the huge productivity gap at site level (Horner and Duff, 2001). There is lack of a research study to identify the possible solutions to improve site level construction productivity of building contractors in Sri Lanka. Accordingly, the aim of the study is to identify the possible solutions to enhance the site level construction productivity of building contractors in Sri Lanka. This was achieved through identifying significant site level construction problems faced by building contractors in Sri Lanka. Finally, reasons and solutions for each critical site level problem was identified.

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2. LITERATURE REVIEW

2.1. SIGNIFICANCE OF CONSTRUCTION PRODUCTIVITY TOWARDS NATION'S ECONOMY

Construction productivity can be defined as the usage of all resources for the production in an effective and efficient way (Dolage and Chan, 2014). Hughes and Thorpe (2014) identified the construction productivity as "the ratio of output to all or some of the resources". These resources basically include materials, labour, equipment, energy, space, information, finance, knowledge and time (Dolage and Chan, 2014). Hence, contractors can use all above resources in effective and efficient manner to increase the construction productivity. However, construction industry always tends to fluctuate with the general economy (Olomolaiye, *et al*., 1998). Hence, productivity of construction industry has become one of the most complicated and broadest aspects.

The construction productivity of a country largely impacts to the nation's economy (Naoum, 2016; Naoum and Hackman, 1996). Therefore, construction industry plays a key role through creating assets for the nation (De Silva *et al*., 2014). Ma, *et al*., (2016) stated that the construction industry always makes an indispensable contribution towards the prosperity of the economy. A greater proportion of Sri Lankan construction industry is also covered by the building construction sector (IMaCS and ICRA Lanka, 2011), hence contractors are often engaged in building construction activities. Site level construction productivity is significant for contractors due to the large involvement of resources at site level. Therefore, Sri Lankan building contractors can earn more profit through increasing their site level construction productivity.

2.2. SIGNIFICANT FACTORS AFFECTING THE CONSTRUCTION PRODUCTIVITY

Productivity is a complex issue due to the influence of numerous factors including labour, material, capital and equipment (Liberda *et al*., 2003). Further, most of the researchers attempted to identify the critical factors affecting the construction productivity in different countries (Lim and Alum, 1995). Accordingly, the following 60 factors were identified as the significant factors impact to the construction productivity.

Table 1: Factors Affecting the Construction Productivity

Factors Affecting the Construction Productivity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Poor site layout	x	x							
Incompetent supervision of subordinators			x	x					
Rework		x	x						
Supremacy of owner/consultant	x								
Incomplete drawing, specification etc.		x							
Material management on site				x	x				
Non-availability of information			x	x					
Worker skills			x						
Design changes			x						
Insufficient knowledge of new technology						x			
Lack of proper incentives to reward good performance							x		
Interruption of site programs						x			
Poor selection of project personnel						x			
Scarcity of material	x	x							
Subcontractor inefficiency	x								
Shortage of multi skilled project personnel						x			
Scarcity of tools and equipment	x	x							
Absenteeism	x	x							
Delay in running bill payment	x								
Lack of contract administration skills						x			

Lack of appraisal for promotion						x			
Lack of experience and training						x			
Low quality material used	x								
Management of tools, equipment and labour				x					
Poor knowledge of scientific techniques						x			
Worker turnover	x							x	
Financial-failure of owner	x								
Scope changes	x			x					
Ineffective delegation of responsibilities						x			
Uncertainties about career prospects within organization						x			
Lack of consultation for decision making						x			
Inspection delay	x	x							
Lack of proper planning and scheduling			x		x				
Difference in construction technique	x								
Slow responses to settle employees' grievances						x			
Unavailability of skilled labours	x								
Adverse weather conditions			x	x					
Worker motivation			x			x			
Lack of shared beliefs between headquarters and site office						x			
Design errors				x			x		
Discrepancies with technical information						x			
Tools/equipment breakdown						x			
Exclusion of site management from contract meetings						x			
Congested work areas			x	x					
Excessive quantity variation	x								
Unbalanced risk	x								
Lack of integration of the management information system						x			
Lack of opportunities to exercise skill/ knowledge						x			
Accidents	x							x	
Work overload	x								
Resentment about management policies						x			
Worker interference							x		x
Working overtime									x
Changing crew members									x
Changing foreman									x
Overcrowding					x				x
Public interruptions	x								
Issue of security	x			x					
Omissions									
Labour strike	x								

[1] (Hughes and Thorpe, 2014)
[2] (Makulsawatudom and Emsley, 2003)
[3] (Hewage and Ruwanpura, 2006)
[4] (Jergeas, 2010)
[5] (Naoum, 2016)
[6] (Naoum and Hackman, 1996)
[7] (Horner and Duff, 2001)
[8] (Lim and Alum, 1995)
[9] (Holt *et al*., 1998)

2.3. IMPORTANCE OF CONSTRUCTION PRODUCTIVITY IMPROVEMENT

Researchers and practitioners found several means to improve the various aspects of construction productivity in the global context (Jergeas, 2010). Number of researches had been conducted on improvement of construction productivity in world-wide as the productivity growth is highly significant to strengthen the market relationships (Myronenko, 2012). As per the analysis of Horner and Duff (2001) during the period of 1976 to 2001, there was a huge room for productivity improvement in the construction industry. Accordingly, many researchers had made efforts to improve the construction productivity (Oglesby *et al*., 1989). Jergeas (2010) identified that improvement in construction productivity needs to be achieved through efficiency, effectivity, increased innovation and technology diffusion. However, this is impossible due to the huge productivity gap at site level (Horner and Duff, 2001). Therefore, identifying possible solutions is significant to improve site level construction productivity of Sri Lankan building contractors to fill the construction productivity gap.

3. RESEARCH METHODOLOGY

Mixed approach was used for this study due to the utilisation of qualitative and quantitative approaches. Initially, an extensive literature review was carried out to identify the site level construction productivity influential factors. Thereafter, a preliminary survey through semi-structured interviews were conducted with the construction industry experts due to the unavailability of secondary information to identify the important factors which have high impact over the site level construction productivity of building contractors in Sri Lanka. Convenience sampling under non-probability sampling technique was used to select sample of respondents. Accordingly, preliminary survey was used to investigate the critical problems influencing the site level construction productivity of contractors in Sri Lanka. This preliminary survey was carried out among 5 experts in the construction industry. Further, Relative Important Index (RII) and content analysis techniques were used for data analysis of preliminary survey.

Table 2: Profile of Preliminary Survey Experts

Respondent	Area of Expertise	Experience
R1	Director, Chartered Quantity Surveyor	45 years
R2	General Manager, Chartered Engineer	24 years
R3	Director, Chartered Quantity Surveyor	25 years
R4	Project Engineer, Senior Quantity Surveyor	26 years
R5	Director, Chartered Quantity Surveyor, Project Manager, Arbitrator, Claims Manager	35 years

A questionnaire survey was carried out to identify the most critical site level problems faced by the building contractors in Sri Lanka. These questionnaires were circulated among a sample of 92 site professionals including the Project Managers, Quantity Surveyors and Civil Engineers, as representatives of the whole population of the building contractors in Sri Lanka from grade CS2 to C3. Accordingly, 49 responses were received and among those respondents 78% were Quantity Surveyors, 16% were Civil Engineers and the rest of 6% were Project Managers. RII technique was used for the data analysis of the questionnaire survey.

Finally, expert interviews were conducted to identify the possible solutions to enhance the site level construction productivity of building contractors. These interviews were conducted among 10 experts who have vast knowledge on site level construction productivity.

Table 3: Profile of Final Expert Interview Survey

Expert	Expertise area	Experience
A	Project Manager	13 years
B	Senior Quantity Surveyor	10 years
C	Director/ Chartered Quantity Surveyor	40 years
D	Assistant General Manager- Estimation and Contracts leading contracting organization	10 years

Expert	Expertise area	Experience
E	Head of the Construction Department	15 years
F	Director of Quantity Surveying in a consultancy firm	10 years
G	Chief Quantity Surveyor in a contracting firm	30 years
H	Chief Executive Officer in a leading contracting organization	10 years
I	Chartered Quantity Surveyor	40 years
J	Chartered Civil Engineer	15 years

The interview was principally focused on the major problems highlighted through the questionnaire survey findings. The aim of the final expert survey was to investigate the reasons for the major problems and possible productivity improvement methods to mitigate those problems from the building contractors. Code based content analysis technique was used to analyse gathered data which facilitated in identifying the critical reasons and solutions for major site level problems faced by the building contractors in Sri Lanka.

4. RESEARCH FINDINGS AND DISCUSSION

4.1. SIGNIFICANCE OF SITE LEVEL CONSTRUCTION PRODUCTIVITY FOR CONTRACTORS

Preliminary survey findings revealed that site level construction productivity has 65% of profitability contribution for contractors and head office level has only 30% of profitability contribution for the contractors. Balanced 5% is covered through the external factors. Site level construction productivity is therefore more important for Sri Lankan contractors. Further, research findings revealed that efficient use of resources, increased profitability, improvement in operations and enhanced image of the company were the five main reasons behind the importance of site level construction productivity for contractors.

4.2. FACTORS INFLUENCING THE SITE LEVEL CONSTRUCTION PRODUCTIVITY OF CONTRACTORS

According to the preliminary survey findings, there are 26 significant factors out of 60 factors which have high impact over the contractors' site level construction productivity in Sri Lanka. Worker motivation is identified as the most influential factor in the site level construction productivity of contractors. However, there are 7 most significant factors identified through the preliminary survey. All those seven factors obtained greater than 0.90 RII value. It provides a clear indication about the significance of the identified five factors and shows the high level of severity over the site level construction productivity.

Table 4: Findings of Preliminary Survey

No	Factor	RII	No	Factor	RII
1	Worker motivation	1.0000	**14**	Scarcity of material	0.8800
2	Worker skills	0.9600	**15**	Subcontractor inefficiency	0.8800
3	Lack of proper planning and scheduling	0.9600	**16**	Shortage of multi skilled project personnel	0.8800
4	Unavailability of skilled labours	0.9600	**17**	Scarcity of tools and equipment	0.8400
5	Incomplete drawings, specification etc.	0.9200	**18**	Absenteeism	0.8400
6	Material management on site	0.9200	**19**	Delay in running bill payment	0.8400
7	Non-availability of information	0.9200	**20**	Lack of contract administration skills	0.8400
8	Incompetent supervisors of subordinators	0.8800	**21**	Lack of appraisal for promotion	0.8000
9	Design and changes	0.8800	**22**	Lack of experience and training	0.8000
10	Insufficient knowledge of new technology	0.8800	**23**	Low quality material used	0.8000
11	Lack of proper incentives to reward good performance	0.8800	**24**	Management of tools, equipment and labour	0.8000
12	Interruption of site programs	0.8800	**25**	Poor knowledge on scientific techniques	0.8000
13	Poor selection of project personnel	0.8800	**26**	Worker turnover	0.8000

4.3. *METHODS TO IMPROVE SITE LEVEL CONSTRUCTION PRODUCTIVITY OF BUILDING CONTRACTORS*

There were 4 main problems identified through the questionnaire findings as workers' skills problems, worker motivation problems, unavailability of skilled labourers, and material management problems. Accordingly, workers' skills problem has become the most influential problem at the site level for the building contractors in Sri Lanka. Therefore, as per the questionnaire survey findings following 4 factors can be considered as the significant productivity problems at site level according to its criticality.

Table 5: Findings of Questionnaire Survey

No	Factor	Very often	Often	Moderately	Rarely	Never	RII	Rank
1	Worker skills	29	15	5	0	0	0.898	1
2	Worker motivation	17	22	10	0	0	0.829	2
3	Unavailability of skilled labours	20	18	9	1	1	0.824	3
4	Material management on site	11	26	10	2	0	0.788	4

Significant reasons for those critical problems and solutions to mitigate those problems by enhancing the site level construction productivity are discussed in below.

4.3.1 IMPROVING WORKERS' SKILLS

As stated by 8 experts, introducing proper training programs is the main solution for workers' skills problem. Further, experts noted that providing proper training for employees under supervisory level and levels above that is possible due to the availability of suitable institutes to train those people. However, it is difficult to find institutes with training programs for bottom level site workers. Therefore, it is vital to introduce proper training programs for labourers around the country to overcome this problem. Experts C, E and H mentioned that they face with challenging circumstances due to the workers without required skills to carry out the site work. Site workers practice to work by following others, whereas that person may also not a skilful person. Accordingly, unavailability of skilled labour can be minimised through these strategies.

- Implement proper training programmes

As per the findings, Sri Lankan government had implemented "Silpa Saviya" programme focusing the people of "Uda Gammana" project areas which is targeted for 15000 trainees with the aim of recruiting them to the construction industry within 1 year period. However, there are only 9500 trainees. Most of bottom level people are unable to bear expenses during the training period. Thereby, this "Silpa Saviya" program pays stipend of Rs. 10000 per month and give Rs. 5000 worth tool box for trainees. However, this program is still not successful due to the lower level of assistance from the contractors. Therefore, the contractors' assistance is essential for the existence and improvement of this programme.

- Employ workers longer period with the company

Experts B, E, and G noted that the second solution to the workers' skill problem is sustaining the workers longer period with the company. There is a responsibility for the top management to treat workers well and keep them with the company by creating a good attitude in employees' mind towards the organisation where workers will gain experience and skills that they required to carry out their job tasks. Expert G stated that if employees work in a same organisation for a longer period will assist them to adapt to the culture of the organisation and then they become loyal to the organisation.

4.3.2 IMPROVING WORKERS' MOTIVATION

Improving workers' motivation is significant for optimising the site level construction productivity. According to the questionnaire survey findings worker motivation problem is the second highest site level construction productivity problem which must be overcome by the Sri Lankan building contractors.

- Pay rewards, incentive and appraise the performance of workers

Findings asserted the noteworthiness of having a proper rewarding system at site level. If contractors can identify the highly-performed team of workers per month or twice a week, workers motivate to provide their fullest effort in carrying out the job tasks. Further, implementing an incentive scheme is also effective in enhancing the worker motivation. Hence, workers try to earn more by enhancing their performance to fulfil their day-to-day requirements.

- Provide facilities for site workers

Findings proved that top level management does not much care about the labourers' necessities including food, accommodation, transportation which will result in decreasing the productivity. Therefore, providing required facilities for workers is significant towards the achievement of higher productivity level.

4.3.3 Enhancing Availability of Skilled Workers

Unavailability of skilled workers was ranked as third highest existing problem at site level construction productivity of contractors in Sri Lanka. The main reason behind this would be the people's trend towards earning money through easy modes. Further, experts mentioned construction industry as a "3D" industry which means "Dirty", "Dangerous" and "Difficult industry". Therefore, construction industry is not attractive compared to the other working environments and not an ease method of earning money. The bottom level construction site jobs involved with hard working and highly hazardous environment. Therefore, nowadays people do not interest in doing construction site jobs.

- Increase the age limit to get licence for three-wheeler and taxi driving

Nowadays young people tends to buy three-wheelers and easily become three-wheeler drivers. CCI, NHDA, NCASL, and CIDA effort to increase the age limit up to 35 years to get three-wheeler driving licence. According to the experts, age limit of 25 years is also good if the policy can be implemented. Then young people will try to learn something till 25 years old without driving three-wheelers or taxis at very young age which will support to eliminate the unavailability of skilled workers issue up to a certain extent.

- Implement Indo-Sri Lanka Economic and Technology Cooperation Framework Agreement (ETCA)

Experts C and J stated that "ETCA agreement" is one of the best methods to eliminate the problem of unavailability of skilled labour. According to the agreement, free labour movement can be done between India and Sri Lanka. Further, experts stated that productivity is very high when considering the Indian labourers compared to the Sri Lankan labourers. However, some people are afraid to implement this "ETCA agreement" due to the concern of arising cultural problems. According to the opinion of experts, recruiting the foreign labourers to work in construction industry and send them back to their motherland after completion of the project is a good solution if Sri Lankan people does not willing to engage in the construction industry.

- Commence Construction Service Force (CSF)

Initial requirement of CSF is to train 25,000 workers and keep them as a force. Then, those skilled workers can be used to fulfil the requirement of skilled labourers at construction sites. However, the government has a rule stating that not to start new units. Government always try to reduce public sector and try to expand the private sector. It is compulsory to produce skilled labourers to work with new technologies. According to the opinion of experts, traditional skills are not supported to work in current construction industry. Therefore, experts stated that though the government has certain rules, doing something to produce skilled labourers is a timely requirement of the country.

- Conduct "RPL" (Recognition through Prior Learning)

According to the findings, the government had implemented RPL program for identified people who has some knowledge about the industry. Hence this programme initially, trains those selected group of people and issues them with a certificate after a proper evaluation. The second stage involves with this is NVQ (National Vocational Qualification) Level 3. RPL passed person has to pay Rs. 5000 or 6000 to carry out NVQ Level 3 which is one of the best ways to qualify the workers with the required skills. However, this is unsuccessful because most of the people do not have sufficient money to get NVQ Level 3. Therefore, it was identified that bottom level people are unable to get a proper training without a payment. Therefore, all the experts stated the importance of government involvement to provide aids to the people who are interested in getting qualifications such as NVQ level 3, which will be an effective strategy to mitigate the problem of unavailability of skilled workers.

4.3.4 CONDUCTING PROPER MATERIAL MANAGEMENT PRACTICES AT SITES

Material management is compulsory due to the availability of the limited resources. Findings revealed that unawareness of ground level people about the wastage and proper way of handling the materials as the main reason behind this problem.

- Educate site workers about the proper usage of material

Nine experts stated that providing the awareness for site workers on effective and efficient usage of material is a responsibility of the management. Normally, site level workers do not have good educational background. Therefore, they do not have proper knowledge on how to use material in an efficient and effective way for their work. Accordingly, educating them is compulsory to enhance the site level construction productivity.

- Conduct workshop or training programmes for site workers

Conduct workshop or training sessions for site workers about the efficient and effective usage of material is identified as the second solution for the material management problem. Findings asserted that site workers are less knowledgeable about procuring material for sites. Supplying material at required time from required quantity and quality is a timely requirement for sites. If site staff is talented, then they can lead labourers and manage material well without any wastage.

- Material reconciliation can be implemented in sites

According to the findings, material reconciliation is a good monitoring system to be implemented. Monitoring materials assists to identify the wastage and misuse of materials. Contractors should give consideration about unwanted usage of material at sites. Experts mentioned that workers at the sites tend misuse materials and if site workers know that material monitoring system is implemented, then they are afraid to misconduct. Accordingly, material reconciliation is compulsory to enhance the productivity.

5. CONCLUSIONS

This research focused on site level construction productivity of building contractors in Sri Lanka. Research findings acknowledged the importance of site level construction productivity for building contractors. Findings proved that there are most critical site level problems faced by building contractors in Sri Lanka, thus it necessitates the implementation of possible solutions to improve site level construction productivity. An expert survey was carried out to the experts in the field of construction industry to identify the capabilities of the government when implementing the solutions for the identified existing critical problems.

Findings asserted that the government can introduce proper training programs to increase the level of productivity. Training programmes for unskilled labourers can also be implemented with the assistance of building contractors. Further, implementing incentive, rewards and appreciation schemes according to the performance of the labourers, educating site workers on proper usage of materials, can be implemented by the building contractors. However, the findings revealed that it is difficult to implement rewarding system by the government due to the high cost involved and the changes in the political environment. Therefore, the building contractors should motivate workers by conducting effective appreciation scheme, rewarding and incentive system to get maximum output from the workers. Further, it is important for the building contractors to concerning about workers' basic facilities as it has high impact over the site level construction productivity. Moreover, implementing "ETCA" agreement will be useful to fulfil the skilful workers' requirement in the building construction industry in Sri Lanka. However, proper material management practices can be implemented effectively through using proper system to educate site people, and proper material monitoring and procurement system. Further, effective supervision of material usage and material storing systems are important in improving the site level construction productivity of building contractors.

6. REFERENCES

De Silva, N., Darmicka, R., and Fernando, E., 2014. Impact of foreign workforce on productivity in foreign-funded infrastructure projects. *Journal of Financial Management of Property and Construction*, *19*(2), 168-183.

Dolage, D.A.R. and Chan, P., 2014. Productivity in Construction-A Critical Review of Research. *Engineer: Journal of the Institution of Engineers, Sri Lanka*, 46(4).

Fulford, R., and Standing, C., 2014. Construction industry productivity and the potential for collaborative practice. *International Journal of Project Management*, 32(2), 315-326.

Hewage, K.N., and Ruwanpura, J.Y., 2006. Carpentry workers issues and efficiencies related to construction productivity in commercial construction projects in Alberta. *Canadian Journal of Civil Engineering*, *33*(8), 1075-1089.

Horner, M., and Duff, R., 2001. *More for less: A contractor's guide to improving productivity in construction*. London: CIRIA.

Hughes, R., and Thorpe, D., 2014. A review of enabling factors in construction industry productivity in an Australian environment. *Construction Innovation: Information, Process, Management*, 14(2), 210-228.

IMaCS and ICRA Lanka. 2011. *Construction Industry in Sri Lanka*. Sri Lanka: IMaCS and ICRA Lanka.

Jergeas, G., 2010. Top 10 areas for construction productivity improvement on Alberta oil and gas construction projects. In *Construction Research Congress 2010: Innovation for Reshaping Construction Practice,* Canada 8-10 May 2010. Alberta: American Society of Civil Engineers, 1030-1038.

Liberda, M., Ruwanpura, J., and Jergeas, G., 2003. Construction Productivity Improvement: A Study of Human, Management and External Issues. *Construction Research Congress*.

Lim, E. and Alum, J., 1995. Construction productivity: Issues encountered by contractors in Singapore. *International Journal of Project Management*, 13(1), 51-58.

Makulsawatudom, A. and Emsley, M., 2003. Factors affecting the productivity of the construction industry in Thailand: the foremen's perception. In *Construction Research Congress: Wind of Change: Integration and Innovation,* United States: 19-21 March 2003. Hawaii: American Society of Civil Engineers, pp. 1-10.

Ma, L., Liu, C., and Mills, A., 2016. Construction labor productivity convergence: a conditional frontier approach. *Engineering, Construction and Architectural Management*, 23(3), 283-301.

Myronenko, Y., 2012. *Productivity – measurement and improvement* (Master's thesis). KTH Royal Institute of Technology.

Naoum, S.G., 2016. Factors influencing labor productivity on construction sites. *International Journal of Productivity and Performance Management*, 65(3), 401-421.

Naoum, S., and Hackman, J., 1996. Do site managers and the head office perceive productivity factors differently? *Engineering, Construction and Architectural Management*, 3(1/2), 147-160.

Navaratna, D., and Jayawardane, A.K., 2007. Total Factor Productivity in the Building Construction Industry in Sri Lanka. *Engineer*, 63-70.

Oglesby, C.H., Parker, H.W. and Howell, G.A., 1989. *Productivity improvement in construction*. New York: McGraw-Hill.

Olomolaiye, P.O., Jayawardane, A.K., and Harris, F., 1998. *Construction productivity management*. Essex, England: Longman.

SUSTAINABLE FACILITIES MANAGEMENT (SFM): A REVIEW OF PRACTICES AND BARRIERS

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ABSTRACT

Practicing sustainability helps Facilities Management (FM) professionals to re-position themselves from traditional FM to strategic support function. However embracing sustainability is a challenging task as FM scopes are firm specific and integrating sustainable practices are puzzling. Yet, incorporating sustainability into FM practice has a great potential and FM professionals are identified at the forefront in delivering sustainability. However, only few FM professionals are able to embrace the sustainability concept into their operations due to various reasons such as; lack of capability, knowledge and skills, financial support and support from government being the major barriers as per theory. Hence, this paper focusses on identifying current FM scope with possible sustainable practices and explores the existing barriers to practice sustainable facilities management (SFM).

A critical literature review was carried out into materials published in referred journals, conference papers and books etc. The findings revealed that, FM scope could be expanded among 15 support services among which building services and management, and real estate management were most commonly cited. In addition, SFM practices were identified in terms of achieving economic, environment and social sustainability. Accordingly, economic sustainability contains 2 strategies and 8 practices whileenvironment sustainability and social sustainability consist of 3 strategies and 11 practices, and 4 strategies and 15 practices respectively. The review further indicated that 32 barriers existing to practice SFM. This showcase that FM professionals need to focus on identifying firm specific FM scope and its sustainable practices by improving their capabilities.

Keywords: *Barriers; Facilities Management (FM); Sustainable Facilities Management (SFM); Support Services.*

1. INTRODUCTION

Buildings are the manifestation for all type of business activities and therefore incorporating sustainable practices in buildings is inevitable. In UK, the built environment is responsible for half of the carbon emissions, one-third of landfills, half of water consumption and one-quarter of all raw materials (Price et al. 2011). This places a high threat among building practitioners and government to make necessary arrangements to adapt sustainable practices. Integration of sustainability in built environment brings many benefits such as; improved productivity, greater financial returns, reduced detrimental effects on the environment and increased reputation (Shah, 2007). Herein, implementing sustainability is now a major obligation and expectation across many businesses and Facilities Management (FM) is identified at the forefront in delivering sustainability in organisation (Chotipanich, 2004). Further, FM is recognised as a “significant contributor or a key actor” in achieving sustainability in the context of built environment (Aune and Bye, 2005). Yet, different definitions and interpretation given for FM prevent creating a common platform to build a theoretical background on definition, scope and practice of FM to practice sustainability in organisations. Therefore, this paper intends to identify FM scope, its practices and thereby provides stratergies to make those practices sustainable subjected to existing barriers.

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To serve this purpose, the paper is organised as follows; firstly it presents the current FM scope and its practices. Secondly, Sustainable Facilities Management (SFM) was reviewed and SFM practices were identified. Finally, barriers which prevent integrating sustainability in to current FM practices were identified.

2. FACILITIES MANAGEMENT PRACTICES

Facilities Management (FM) is one of the emerging disciplines in the millennium era (Barrett and Baldry, 2003; Lomas, 1999). It is recognised and acknowledged by various organisations for managing and facilitating the built environment effectively (Chotipanich and Lertariyanun, 2011). Accordingly, FM is seen as a multi-disciplinary profession which covers a variety of activities, actions, roles, responsibilities and knowledge (Jones, 2000). However, the nature of FM is rapidly evolving and somewhat fluid (Durodola, 2009). This is evidenced through the contrasting definitions provided for the profession by different researches over the decade. For instance, the evolution of FM can be recognised through US Library of Congress (1989) definition, in which physical management of the built facility is stated as the function of FM. Whereas recent definitions provided by the professional institutes namely International Facility Management Association (IFMA, 2016) and British Institute of Facilities Management (BIFM, 2016) highlight FM as a multi-disciplinary discipline, which integrates people, process, place and technology to ensure the functionality of the built environment. This shows the shift of FM practices from being narrowly defined set of functional tasks to an integrated management approach to achieve corporate goals (Jones, 2000).

The definitions also contradict in identifying the managerial level of FM to distribute the works. For example, Nourse (1990) states that FM professionals function at the operational level and not aware of strategic function in organisations, whilst Becker (1990) highlights only the managerial function. This showcases the different perceptions of researchers. However, the evolution of FM is recognised in the later definitions provided by Nutt (1999) in which the author stressed that FM professionals are to function at all three (03) managerial levels i.e. top management, middle management and operational management. This means that FM is not merely functional at the operational level as it has been construed earlier rather it is more focussed on strategic decision making process to add value to the core objectives of an organisation (Alexander, 2003).

Further, definition for FM is very vague in establishing appropriate scope for FM in organisation because Barrett and Baldry (2003) and IFMA (2016) define FM as a multi-dimensional profession dealing with multiple support services. Here, FM scope is regarded as the various support services performed in the organisation. Initially, as of Becker (1990) FM profession was meant to operate hardware services of organisation i.e. buildings and their systems, equipment and furniture. But later FM profession was emphasised upon dealing with software services such as; people, place, process, space and technology etc. (Alexander, 1996; Nutt, 1999; BIFM, 2016; IFMA, 2016). This clearly demonstrates that FM scope is no more limited to physical aspects of buildings rather it is evolving and intends to embrace the practice of intangible resources of organisation i.e. involvement of FM practice in human resources, marketing management, information technology and workplace management etc. However, it is stated that FM professionals fail to determine the scope of FM, where real values can be added to the organisation through adaptation of appropriate support services (Boateng, 2011). This is due to the reason that FM have numerous definitions and interpreted differently in organisations, regions and countries, which caused confusion in the selection of FM scope for an organisation.

Furthermore, Owen (as cited in Durodola, 2009) affirm that FM profession can be better understood by exploring the scope and practice of FM and cannot be adequately ring-fenced by one definition or common statement (Durodola, 2009). Because, FM theory, practice and scope are broad in nature and continuously broadening due to more practitioners join the league of FM (Boateng, 2011). Hence, Table 1 presents the possible support services which could be performed in an organisation and thereby to define the scope of FM in an organisation.

Table 1: Support Services of FM

	Support services of FM	**Sources**										**Frequency**	**Percentage**
S1	Building services and management	1	2	3	4	5	6	7	8	9	10	𝍸 𝍸	100%
S2	Real estate management	1	2	3	4	5	6		8	9	10	𝍸 IIII	90%
S4	Property/Project management	1		3	4		6	7		9	10	𝍸 II	70%

S3	Information technology			3		5	6		8	9	10	~~IIII~~ I	60%
S5	Human resources management			3		5	6		8	9		~~IIII~~	50%
S6	Risk management		2	3	4		6		8			~~IIII~~	50%
S7	Quality management		2	3			6			9		IIII	40%
S8	Space planning and management		2		4				8		10	IIII	40%
S9	Office management	1			4				8		10	IIII	40%
S10	Operations administration/ Management				4	5		7				III	30%
S11	Planning and programming			3	4			7				III	30%
S12	Employee support services			3	4						10	III	30%
S13	Marketing management					5			8			II	20%
S14	Law				4			7				II	20%
S15	Finance management				4					9		II	20%

Sources;
[1] Thomson (1991)
[2] Kincaid (1994)
[3] Then (1999)
[4] Chotipanich (2004)
[5] Owen (as cited in Boateng, 2011)
[6] Boateng (2011)
[7] Then and McEwan (2004)
[8] Zheng (2012)
[9] Manjula *et al*. (2015)
[10] Isa *et al*. (2016)

In Table 1, building services and management is highlighted by all researchers with 100% agreement, whilst real estate management and property management are highlighted by 90% and 70% of the sample. This evidences the previous findings on FM being considered as an old fashioned profession, which operates in hardware services i.e. in the field of repairs, and maintenance in organisations. However, the evolution of FM scope can be predicted with the expansion of support services. This can be evidenced through information technology to finance management support services with receiving a sample in percentages varying from 60% to 20%. For example, Thomson (1991) specify some basic services to support the core objective of the organisations such as; building services and management, real estate management and property management etc. Later years, the FM scope evolved embracing many support services for the purpose of achieving the core objectives of the organisation such as; finance management, law, employment support services and space planning and management etc. This shows that FM scope in organisation are not limited rather very broad in nature and expands with innovation and integration of new technology.

Moreover, FM scope and its practices are not adapted as same for all organisation rather it is organization specific and differs in terms of facility features, organisational scale, business sector, organisation characteristics, culture and context where it is operated (Chotipanich, 2004). Hence, selection of appropriate FM scope and practices are very important and a hectic challenge borne by FM professional inside an organisation. Accordingly, 15 support services are identified in Table 1 and each of these support services may compromise of several FM practices. Moreover, a few FM practices may belong to several support services i.e. the practice of conducting marketing programmes and providing special promotions and campaigns may belong to real estate management or marketing management support services depending upon the business or industry the FM involve in. Thus, Figure 1 presents the possible FM practices that FM professionals can perform in each of the support services identified in Table 1.

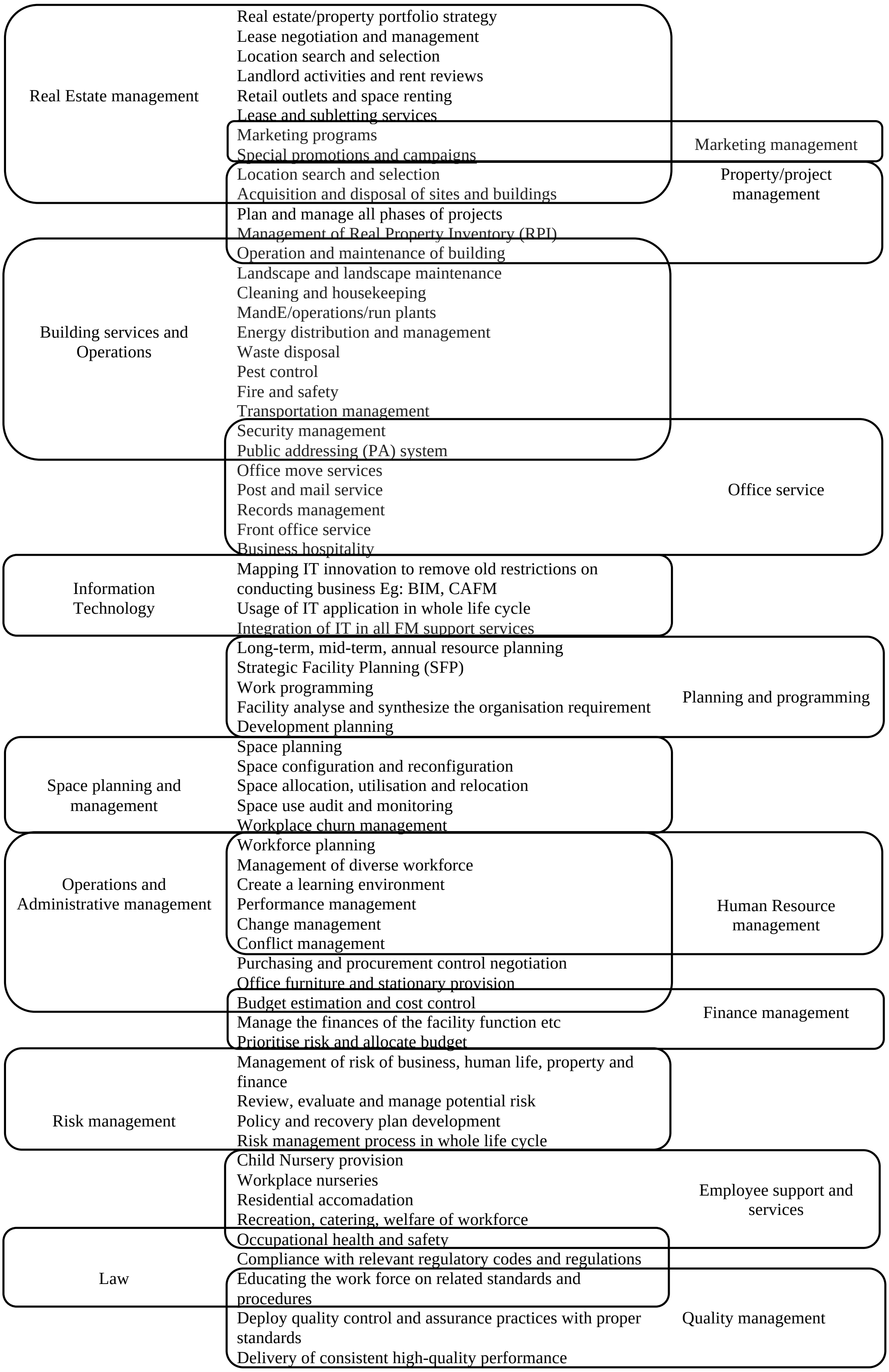

Figure 1: FM Support Services and Practices
(Source; Chotipanich, 2004)

3. SUSTAINABLE FACILITIES MANAGEMENT (SFM)

Sustainability concept came in to existence formally, consequent to the publication of Brundtland Commission Report 1980, in which sustainability is defined as “development that meets the needs of the present generation without compromising future generations to meet their own needs” (WCED, 1987). This awareness created a growing concern on many building operators and owners to showcase interest in integrating sustainable practices into buildings (Nielsen, Jensen and Jensen, 2009) due to the numerous benefits such as; cost reduction, improved productivity, improved quality of life and reduced impact on environment (Zuo and Zhao, 2014). Henceforth, sustainability is now a major obligation and expectation across many businesses (Stern, 2007). Consequently, buildings being the manifestation for all type of business activities, implementation of sustainable practices in buildings is inevitable (Elmualim *et al.*, 2010). Moreover, a holistic approach is needed in addressing sustainability covering all aspects i.e. economic, environment and social elements which is known as “triple bottom line concept” in implementing sustainability in buildings (Elmualim *et. al.*, 2009). Hence, practicing sustainability in a holistic manner addressing all three (03) elements are very important for any building practitioner. Herein, FM professionals are identified at the forefront in delivering sustainability, adapting organisational behavioural changes and who are in capacity to influence individual behavioural pattern of organisations to integrate sustainability (Meng, 2014).

Moreover, sustainability is influenced in building design and construction leading Sustainable Facilities Management (SFM) to be gradually recognized (Meng, 2014) and it is evolved in parallel with sustainable development and climate change concerns (Shah, 2007). In addition, the recognition of SFM among building practitioners is caused due to the challenges exist in built and natural environment today. For example challenges such as; carbon emission, landfills, water consumption and usage of raw materials etc. place a high threat among building practitioners and government to make necessity arrangements and urged for adaption of sustainable practices (Price *et al*. 2011). Accordingly, FM professionals too were, pressurised to practice sustainability to reduce the adverse effects caused (Meng, 2014).

Shah (2007) defined SFM as “delivery of sustainability within FM”. In another definition provided by IFMA (2016) defined 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 in all FM practices.

Hence, this shift in FM is described as “sustainable movement” for FM today (Meng, 2014). This can be regarded as an opportunity to establish FM in the league in delivering sustainability, yet lack of specialist knowledge, capabilities, tools and case study materials are seen as major barriers (Loch, 2000). Adding to this Meng (2014) specify that the implementation of sustainable practice is not easy or straightforward. However, Bosch and Pearce (2003) argue that embracing sustainability in buildings are a realistic goal despite its complexity. Hence, to practice SFM, objectives, strategies and practices are needed. The Table 2, shows the possible SFM practices with appropriate strategies that could be integrated with current FM practices.

Table 2: SFM Objectives, Strategies and Practices

SFM objectives	Strategies	SFM practices	Sources
Achieving Environment Sustainability	Taking account of natural capacity	Assess and mitigate wider environmental impacts (e.g. water supply, sewerage, transport, waste, etc)	Shah, 2007
		Respond to projected impacts of climate change	
	Optimising environmental benefits	Minimise energy demand and achieve carbon neutrality	Akadiri *et al.*,2012; TEFMA, 2004; Shah, 2007
		Optimise efficiency of materials use	
		Maintain and enhance biodiversity	
		Aim to conserve resources such as; water, land, energy and material	
	Minimising negative impacts	Reduce, reuse, recycle, recover waste	
		Reduce emissions to air, land and water	
		Reduce transport impacts	Shah, 2007
		Protect ecological resources	
		Protect archaeological and historically valuable resources	

Achieving Economic Sustainability	Ensure economic viability and improving processes	Use technologies and material consistent with sustainability principles	
		Keep up-to-date with advances in construction technologies	Shah, 2007; TEFMA, 2004
		Use cost and benefit on whole life value basis	
		Manage supply chain effectively	
		Keep up-to-date with regularity and planning requirements	
		Maximise range of economic benefits including flexibility of use	Shah, 2007
	Enhancing business opportunities	Meet national, regional and local economic strategy	
		Capitalise funding for more sustainable development	TEFMA, 2004
Achieving Social Sustainability	Optimising opportunities and social benefits	Create usable public and private space to deliver successful communities (better workplace)	Shah, 2007 TEFMA, 2004
		Improve health wellbeing, accessibility and security of community	Akadiri *et al.*,2012; Shah, 2007 TEFMA, 2004
		Enhance employment and skills development opportunities for the local community	
	Community Involvement and Development	Promoting sustainable communities through planning and design	Shah, 2007; TEFMA, 2004
		Consider and include aspects in the project that will enhance community development.	TEFMA, 2004
	Engaging stakeholders	Consult with public authorities, general public and involve other stakeholders and respond accordingly	Shah, 2007; TEFMA, 2004
		Include stakeholders in every stage of the facilities management	
		Consult and manage expectations of stakeholders on changes to ongoing use and operation	
	Minimising negative impacts	Plan for effective public and private transport use	
		Control nuisance (noise, dust, light etc)	Shah, 2007
		Ensure secure side in construction	
		Ensure health and safety of workers and local community	Akadiri *et al.*,2012; Shah, 2007 TEFMA, 2004
		Protect, enhance and maintain appropriate social access to environmentally sensitive areas	Shah, 2007
		Assess and mitigate flood risk	
		Design for crime prevention	Akadiri *et al.*,2012

Sustainability can be met upon three (03) main aspects of sustainability known as "triple bottom line" concept i.e. environment, economic and social aspects. Hence, achieving sustainability in terms of these three (03) aspects are very essential. For that purpose, SFM strategies and practices are identified aiming to achieve these three (03) objectives as presented in Table 2. Environment sustainability incorporates three (03) strategies and eleven (11) FM practices, economic sustainability includes two (02) strategies and eight (08) practices, while social sustainability unites four (04) strategies and 15 practices, respectively. Hence, adhering to these practices and strategies of sustainability will lead FM professional to practice SFM effectively. However, it is emphasised that only few FM professionals are able to embrace the sustainability criteria into their operations (Lai and Yik, 2006). This is due to several barriers in practicing sustainability in organisation and these factors are discussed in the following section.

4. Barriers for SFM Practices

Despite the importance of sustainability has gained in last few decades, still intergrating sustainability into FM practice is challenging. Table 3 lists the possible barriers exist in terms of practicing SFM.

Table 3: Barriers in Practicing SFM Practices

Code	Barriers	Sources	Frequency	Percentage
SB1	Lack of capability and knowledge	[1-20][22-27]	26	96%
SB2	High cost	[1][3-23][25][26]	24	89%
SB3	Lack of government initiatives or support	[4-7][9][11][12][15-17] [19] [23-27]	16	59%
SB4	Lack of interest or demand from clients	[3][4][6][8-11][16][17][19] [20][22][23] [25]	14	52%
SB5	Lack of Green building guides or codes or regulation	[3][6][13][14][16][17][22-25]	10	37%
SB6	Lack of Technology	[3-7][10][14][16][17] [20][22][24-26]	12	44%
SB7	Lack of communication and interest among stakeholders	[2-4][10][12-16][22][27]	11	41%
SB8	Risks and uncertainty	[11][13][14][16][22-26]	09	33%
SB9	Project complexity	[4][6][10][12][13][16][19][24] [26]	09	33%
SB10	Scarcity of resources	[2][5][6][10][13][23][25]	07	26%
SB11	Resistance to change	[4][12][13][15][16][24]	06	22%
SB12	Duration of project	[4][12-14][19][22][26]	07	26%
SB13	Lack of authority and support in forcing green building laws	[3][9][14][22-24]	06	22%
SB14	Lack of promotion	[7][11][16][18][25][26]	06	22%
SB15	Lack of training	[14][16][17][19][24]	05	19%
SB16	Distrust of green building products	[2][6][12][24]	04	15%
SB17	Lack of finance	[6][9][11][20]	04	15%
SB18	Culture, attitude, norms and behaviour of people	[2][7][9][15]	04	15%
SB19	Rigid requirement	[12][13][23][26]	04	15%
SB20	Lack of certificate	[11][14][15][23]	04	15%
SB21	Inadequate building laws	[2][10][11][27]	04	15%
SB22	Political governmental issues	[6][9][11]	03	11%
SB23	High market values	[17][23][25]	03	11%
SB24	Improper property valuation system	[18][23][26]	03	11%
SB25	Long payback period	[20][26]	02	07%
SB26	Project location	[3][6]	02	07%
SB27	Poor quality of green building design	[1]	01	04%
SB28	Company size	[17][19]	02	07%
SB29	Lack of green building material suppliers	[20][23]	02	07%
SB30	Insurance liability issues	[20][23]	02	07%
SB31	Lack of tested, reliable green building materials locally	[10][12]	02	07%
SB32	Bureaucracy	[13]	01	04%

Sources;
[1] Bond (2011)
[2] Winston (2010)
[3] Williams and Dair (2007)
[4] Hwang and Tan (2010)
[5] Ghaffarian Hoseini *et al*. (2013)
[6] Luthra *et al*. (2015)
[7] Zhang *et al*. (2012)
[8] Zhao *et al*. (2015)
[9] Zhang and Wang (2013)
[10] Du *et al*. (2014)
[15] Kasai and Jabbour (2014)
[16] Djokoto *et al*.(2014)
[17] Zainul Abidin *et al*.(2013)
[18] Nahmens and Reichel (2013)
[19] Opoku and Ahmed (2014)
[20] Gou *et al*.(2013)
[21] Qian *et al*.(2015)
[22] Zhang *et al*. (2011)
[23] Häkkinen and Belloni (2011)
[24] Petri *et al*. (2014)

[11] Persson and Grönkvist (2015)	[24] Samari *et al*. (2013)
[12] Lam *et al*. (2009)	[26] Shi *et al*. (2013)
[13] Hwang and Ng (2013)	[27] Love *et al*. (2012)
[14] Zhang *et al*.(2011)	

Accordingly, Table 3 presents 32 barriers in terms of practicing SFM. Among these barriers, lack of capability and knowledge is identified as the major barrier with 96% percentage of agreement of the sample, while high cost was identified as the second important barrier with 89% agreement. Moreover, 14 barriers were classified as important through achieving more than 20% agreement from the sample while the rest of the 18 barriers achieved less than 20% of agreement, considered least important barriers. . Ultimately, being, lack of capability and skills were identified to be the most important barrier in practicing SFM, the finding showcases the need of researching capabilities of FM professionals to practice sustainability.

5. CONCLUSIONS

This paper critically reviewed the FM scopes in order to practice sustainability in various support services. Yet, FM support services and its practices are identified to be organisation specific providing tailored service. Herein, this study identifies fifteen (15) support services and relevant FM practices. Moreover, to integrate sustainability this study adapts the triple bottom line concept of sustainability and establishes suitable strategies, objectives and practices to the current FM practice. For example, environment sustainability incorporates three (03) strategies and eleven (11) FM practices, economic sustainability includes two (02) strategies and eight (08) practices, while social sustainability unites four (04) strategies and (15) practices. However, SFM practices are challenging and 32 barriers were identified which prevents practicing sustainability. Here, lack of capability and knowledge being highlighted by 96% of researchers whilst high cost was agreed by 89% of researchers. Hence, the findings reveals that the researcher should focus on identifying SFM practices in depth in terms of each specific support services and to examine the barrier “lack of capability” which prevents practicing SFM.

6. REFERENCES

Akadiri, P. O., Chinyio, E. A., and Olomolaiye, P. O. (2012). Design of a sustainable building: A conceptual framework for implementing sustainability in the building sector. *Buildings*, 2(2), 126-152.

Alexander, K. (1996). A Strategy for Facilities Management. *Facilities*, 12(11), 6-10.

Alexander, K. (2003). A strategy for facilities management. *Facilities*, 21(11/12), 269-274.

Aune, M. and Bye, R., 2005. Buildings that learn – the role of building operators. In: *European Council for an Energy Efficient Economy (ECEEE) summer study; What works and who delivers*?. Sweden. 415-422.

Barrett, P. and Baldry, D. (2003). *Facilities management*. Osney Mead, Oxford, OX: Blackwell Science.

Becker, F. (1990). *The total workplace.* New York: Van Nostrand Reinhold.

BIFM, (2016). BIFM - *Facilities Management Introduction.* [online] Bifm.org.uk. Available from: http://www.bifm.org.uk/bifm/about/facilities [Accessed 26 Sep. 2016].

Boateng, E., 2011. *The future of facility management in Finland*. (B.Sc). School of Business and Services Management, Jamk University of Applied Sciences.

Bond, S. (2011). Barriers and drivers to green buildings in Australia and New Zealand. *Journal of Property Investment and Finance*, 29(4/5), 494-509.

Bosch, S.J. and Pearce, A.R., 2003. Sustainability in public facilities: Analysis of guidance documents. *Journal of Performance of Constructed Facilities*, 17(1), 9-18.

Chotipanich, S. and Lertariyanun, V., 2011. A study of facility management strategy: the case of commercial banks in Thailand. *Journal of Facilities Management*, 9(4), 282-299.

Chotipanich, S., 2004. Positioning facility management. *Facilities*, 22(13/14), 364-372.

Djokoto, S.D., Dadzie, J. and Ohemeng-Ababio, E., 2014. Barriers to sustainable construction in the Ghanaian construction industry: consultants perspectives. *Journal of Sustainable Development*, 7(1), 134.

Du, P., Zheng, L.Q., Xie, B.C. and Mahalingam, A., 2014. Barriers to the adoption of energy-saving technologies in the building sector: A survey study of Jing-jin-tang, China. *Energy Policy*, 75, 206-216.

Durodola, O.D., 2009. Management of hotel properties in south-western Nigeria: facilities management perspective Doctoral dissertation, Covenant University.

Elmualim, A., Czwakiel, A., Valle, R., Ludlow, G. and Shah, S. 2009. The Practice of Sustainable Facilities Management: Design Sentiments and the Knowledge Chasm. *Architectural Engineering and Design Management*, 5(1), 91-102.

Elmualim, A., Shockley, D., Valle, R., Ludlow, G. and Shah, S., 2010. Barriers and commitment of facilities management profession to the sustainability agenda. *Building and Environment*, 45(1), 58-64.

GhaffarianHoseini, A., Dahlan, N., Berardi, U., GhaffarianHoseini, A., Makaremi, N. and GhaffarianHoseini, M. (2013). Sustainable energy performances of green buildings: A review of current theories, implementations and challenges. *Renewable and Sustainable Energy Reviews*, 25, 1-17

Gou, Z., Lau, S. and Prasad, D. (2013). Market Readiness And Policy Implications For Green Buildings: Case Study From Hong Kong. *Journal of Green Building*, 8(2), 162-173.

Häkkinen, T. and Belloni, K. (2011). Barriers and drivers for sustainable building. *Building Research and Information*, 39(3), 239-255

Hwang, B. and Ng, W. (2013). Project management knowledge and skills for green construction: overcoming challenges. IEEE Engineering Management Review, 41(2), 87-103.

Hwang, B. and Tan, J. (2010). Green building project management: obstacles and solutions for sustainable development. *Sustainable Development*, 20(5), 335-349

IFMA (2017). *What is FM - Definition of Facility Management.* [online] Ifma.org. Available from: https://www.ifma.org/about/what-is-facility-management [Accessed 13 Jun. 2017].

Isa, N.M., Kamaruzzaman, S.N., Mohamed, O., Jaapar, A. and Asbollah, A.Z., 2016. Facilities Management Practices in Malaysia: A Literature Review. In *4th International Building Control Conference 2016 (IBCC 2016)*,(Vol. 66, p. 00054). 07 Mar 2016 - 08 Mar 2016. Pullman Bangsar Hotel, Kuala Lumpur.

Jones, O., 2000. Facility management: future opportunities, scope and impact. *Facilities*, 18(3/4), 133-137.

Kasai, N. and Jabbour, C. 2014. Barriers to green buildings at two Brazilian Engineering Schools. International *Journal of Sustainable Built Environment*, 3(1), 87-95.

Kincaid, D., 1994. Integrated facility management. *Facilities*, 12(8), 20-23.

Lai, J.H. and Yik, F.W., 2006. Knowledge and perception of operation and maintenance practitioners in Hong Kong about sustainable buildings. *Facilities*, 24(3/4), 90-105.

Lam, P., Chan, E., Chau, C., Poon, C. and Chun, K. 2009. Integrating Green Specifications in Construction and Overcoming Barriers in Their Use. *Journal of Professional Issues in Engineering Education and Practice*, 135(4), 142-152.

Loch, B., 2000. Avoiding the usual suspects. *Facilities*, 18(10/11/12), 368-370.

Lomas, D.W., 1999. Facilities management development in Hong Kong. *Facilities*, 17(12/13), 470-475.

Love, P., Niedzweicki, M., Bullen, P. and Edwards, D. 2012. Achieving the Green Building Council of Australia's World Leadership Rating in an Office Building in Perth. *Journal of Construction Engineering and Managemen*t, 138(5), 652-660

Luthra, S., Kumar, S., Garg, D. and Haleem, A., 2015. Barriers to renewable/sustainable energy technologies adoption: Indian perspective. *Renewable and sustainable energy Reviews*, 41, 762-776.

Manjula, N.H.C., Dissanayake, D.M.P.P. and Rajini, P.A.D., 2016. Facilities Management Approaches for Sustainability. In *6th International Conference on Structural Engineering and Construction Management*, 11th - 14th December 2016, Kandy, Sri Lanka

Meng, X. 2014. The role of facilities managers in sustainable practice in the UK and Ireland. *Smart and Sustainable Built Environment*, 3(1), 23-34.

Nahmens, I. and Reichel, C. 2013. Adoption of high performance building systems in hot- humid climates – lessons learned. *Construction Innovation*, 13(2), 186-201.

Nielsen, S.B., Jensen, J.O. and Jensen, P.A., 2009. Delivering sustainable facilities management in Danish housing estates. In 2nd *International Conference on Sustainability Measurement and Modelling ICSMM 09© CIMNE*, Barcelona. pp. 135.Nourse, H. 1990. Managerial real estate. Englewood Cliffs, N.J.: Prentice-Hall.

Nutt, B., 1999. Linking FM practice and research. *Facilities*, 17(1/2), 11-17.

Opoku, A. and Ahmed, V. 2014. Embracing sustainability practices in UK construction organizations. *Built Environment Project and Asset Management*, 4(1), 90-107.

Persson, J., and Grönkvist, S. 2015. Drivers for and barriers to low-energy buildings in Sweden. *Journal of Cleaner Production*, 109, 296-304.

Petri, I., Rezgui, Y., Beach, T., Li, H., Arnesano, M. and Revel, G. 2014. A semantic service oriented platform for energy efficient buildings. *Clean Technologies and Environmental Policy*, 17(3), 721-734

Price, S., Pitt, M. and Tucker, M., 2011. Implications of a sustainability policy for facilities management organisations. *Facilities*, 29(9/10), 391-410.

Qian, Q., Chan, E. and Khalid, A. 2015. Challenges in Delivering Green Building Projects: Unearthing the Transaction Costs (TCs). *Sustainability*, 7(4), 3615-3636

Samari, M., Ghodrati, N., Esmaeilifar, R., Olfat, P. and Mohd Shafiei, M. 2013. The Investigation of the Barriers in Developing Green Building in Malaysia. *Modern Applied Science*, 7(2). 1-10.

Shah, S. 2008. *Sustainable Practice for the Facilities Manager*. 1st ed. New York, NY: John Wiley and Sons.

Shi, Q., Zuo, J., Huang, R., Huang, J. and Pullen, S. 2013. Identifying the critical factors for green construction – An empirical study in China. *Habitat International*, 40, 1-8

Shiem-Shin Then, D., 1999. An integrated resource management view of facilities management. *Facilities*, 17(12/13), 462-469.

Stern, N.H., 2007. *The economics of climate change: the Stern review*. Cambridge University press.

Tertiary Education Facilities Management Association (TEFMA), 2004. A Guide to Incorporating Sustainability into Facilities Management. Austrailia. Available from: https://www.ifma.org/about/what-is-facility-management [Accessed 13 Jun. 2017].

Then, S.S.D. and McEwan, A., 2004. Capturing knowledge from facilities management practice-issues and possibilities. In: *Hong Kong 2004 CIBW70 International Symposium*, Hong Kong. pp. 251-263Thomson, T., 1991. Matching services to business needs: resourcing routine services and projects. *Facilities*, 9(6), 7-13.

US Library of Congress, 1989. In Mole, T. and Taylor, F. 1992. Facility Management: Evolution or Revolution. In Barrett, P. (Ed.), 1993. *Facilities Management – Research Directions*, London: Surveyors Holdings Limited.

WCED. 1987. *Our Common Future*. World Commission on Environment and Development. Oxford University Press. Oxford, New York.

Williams, K. and Dair, C. 2007. What is stopping sustainable building in England? Barriers experienced by stakeholders in delivering sustainable developments. *Sustainable Development*, 15(3), 135-147.

Winston, N. (2010). Regeneration for sustainable communities? Barriers to implementing sustainable housing in urban areas. *Sustainable Development*, 18(6), 319-330.

Zainul Abidin, N., Yusof, N. and Othman, A. 2013. Enablers and challenges of a sustainable housing industry in Malaysia. *Construction Innovation*, 13(1), 10-25.

Zhang, X., Platten, A. and Shen, L. 2011. Green property development practice in China: Costs and barriers. *Building and Environment*, 46(11), 2153-2160.

Zhang, X., Shen, L., Tam, V. and Lee, W. 2012. Barriers to implement extensive green roof systems: A Hong Kong study. *Renewable and Sustainable Energy Reviews*, 16(1), 314-319.

Zhang, Y. and Wang, Y., 2013. Barriers' and policies' analysis of China's building energy efficiency. *Energy Policy*, 62, 768-773.

Zhao, D.X., He, B.J., Johnson, C. and Mou, B., 2015. Social problems of green buildings: From the humanistic needs to social acceptance. *Renewable and Sustainable Energy Reviews*, 51, 1594-1609.

Zheng, L., 2012. Developing the understanding of facility management demand by small and medium enterprises in the UK and China. MSc. The Bartlett School of Graduate Studies - UCL

Zuo, J. and Zhao, Z.Y., 2014. Green building research–current status and future agenda: A review. Renewable and *Sustainable Energy Reviews*, 30, 271-281.

THE IMPORTANCE OF DISASTER MANAGEMENT AND IMPACT OF NATURAL DISASTERS ON HOSPITALS

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ABSTRACT

The purpose of this research is to study and explore the importance of hospitals in natural disaster events and to identify the impacts on the hospitals in natural disaster events. A disaster is an unforeseen event, which can overwhelm the capacity of the affected people to manage its impact. Many people are periodically exposed to natural disasters in their life, and most disasters, or more correctly hazards that lead to disasters, cannot be prevented. However, their effects can be mitigated. Disaster management efforts aim to reduce or avoid the potential losses from hazards, assure prompt and appropriate assistance to the victims of a disaster, and achieve a rapid and effective recovery. It is crucial that hospitals remain safe and functional during and after disasters. Health facilities at all levels deserve special attention in the case of natural disasters as they must continue the work of current patient treatment within their facilities and provide additional care for persons injured by the disaster event. Disaster management becomes even more important for hospitals as the health sector has been particularly vulnerable to the damage caused. For this study, secondary information was retrieved from the Internet on sudden-onset natural disasters in different parts of the world was collected. This study found some barriers and deliverables for disaster managers that could mitigate the risk of a natural disaster's impact on a hospital. Accordingly, this paper evaluates the importance of disaster management for hospitals and the challenges that need to be considered during the disaster response.

Keywords: *Hospitals; Impact; Natural disasters; Mitigation; Strategy.*

1. INTRODUCTION

Huder (2012) defines disaster events as a "pebble drop in a pond where the pebble impacts the surface of the pond and ripples outwards". In the case of a natural disaster, the impact is often felt throughout a community. A disaster can be an unforeseen event; it can overwhelm the capacities of those affected, and disrupt many normal human activities (Tomasini and Van Wassenhove, 2004). Many people are periodically exposed to at least one natural disaster in their life, and most disasters, or more correctly hazards that lead to disasters, cannot be prevented; however, their effects can be minimized (Lin Moe *et al*, 2006). As communities worldwide face an increasing frequency and variety of disasters, there is an urgent need to reduce the risk from disasters (Lin Moe *et al*, 2006). Within this context, disaster management is significant as it can mitigate some effects such efforts aim to reduce or avoid the potential losses from hazards, assure prompt and appropriate assistance to the victims of disaster, and achieve a rapid and effective recovery. Disaster management becomes even more important for hospitals as the health sector has been particularly vulnerable to disaster. Health facilities, at all levels, deserve special attention in the case of natural disasters, as they must continue patient treatment and as well as care for those injured by the event (Eybpoosh, Dikmen, and Talat Birgonul, 2011). At any given time, hospitals have a population of patients, staff, visitors, and transient patients, but in a disaster event, the number may rapidly and substantially increase. The security and safety of all patients and occupants must be secured whilst continuing ongoing treatments and support services (Salamati *et al*, 2016). It is also important that promotion and prevention programs are not suspended, such as prenatal care and hemodialysis. As such, to ensure the continuity of service in the case of a natural disaster, a hospital must develop and implement formal plans to deal with such difficult events.

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The construction plan of the hospital building and its equipment must ensure it remains in a serviceable condition however in the poor hospital authorities recognize these facts, which is why they usually draw up plans to deal with disasters and develop design strategies that understand and mitigate risk by using a specially designed construction plan (Kenny, 2012) but between 1990 and 2010, more than 100 hospitals and more than 650 health centers were affected across the world as a result of natural disasters; in these situations, many hospitals either collapsed or were left in a vulnerable condition requiring evacuation (Bosher and Dainty, 2011). This suggests that, without proper planning in a disaster event, hospitals may face a difficult situation when trying to continue to deliver their services to patients, particularly as the hospital may be experiencing some chaos. Accordingly, this paper explores the importance of hospitals in disaster events and the impact of natural disasters on hospitals. The researcher in this study attempt to understand the importance of hospitals in natural disaster events, and also mitigate the risk of natural disasters on hospitals, and focusing on continuity of health services during natural disaster events. This paper is structured as follows: firstly, the concept of disaster and the importance of disaster management in hospitals are reviewed from the latest literature. Secondly, some challenges for hospital disaster management will be discussed, and finally, the paper provides a discussion that focuses on a better vision and appropriate framework in order to better manage hospitals in natural disaster events.

2. Literature Review

2.1. The Concept of Disaster

The World Health Organisation (2006) defines disaster as "any occurrence that causes damage, ecological disruption, the loss of human life, or the deterioration of health and health services, on a scale sufficient to warrant an extraordinary response from outside the affected community or area. The disaster has been defined by many researchers; for example, it is identified by Burnham (2013) as an unforeseen event that is suddenly overwhelming". McEntire (2015) describes disaster as "a destructive, deadly and disruptive incident that happens when a hazard connects with humans". Disasters can happen abruptly and can be classified as a dangerous and calamitous incident, which overwhelms and disrupts infrastructures (Ardalan, 2013). From a different perspective, it can be described on a household scale, where a disaster can cause major sickness and social calamity, or an essential economic catastrophe (Shaluf, 2007). It is clear from the above definitions that a disaster causes damage not only to human lives but also to constructed entities (Rathore and Gosney, 2015). However, there are two common points in all of the aforementioned descriptions, which are time and location. Indeed, Al-Dahash *et al.* (2016) confirm that disasters are defined based on time and space. Also, Alexander (2003, cited by Al-Dahash *et al.*, 2016) described the disaster as a combination of vulnerability, lack of measures, and hazards that require the implementation of appropriate measures for planning, and the use of appropriate resources in order to mitigate the adverse impacts. Scientists have pointed out that natural disaster occurrences have significantly increased and intensified in the last 30 years. In Figure 1, the statistics demonstrate the number of earthquakes across the world between 2000 and 2015.

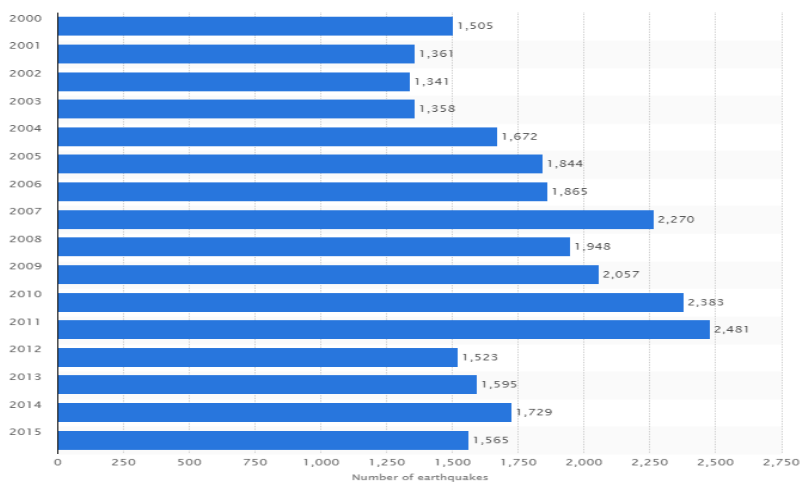

Figure 1: Development of the Number of Earthquakes (M5+) Worldwide between 2000 and 2015
(Source: Gulyaeva and Arikan, 2016)

Although there are some similarities between definitions, such as time, space, and their unforeseen nature, there is no universal definition of disaster events (Shaluf *et al*, 2003). Disaster events may happen in two different types such as; natural, and manmade. In 2015, the total number of earthquakes with a magnitude of more than five in the richter scale reached nearly 1600. While the technology used to record and find the source of earthquakes has improved since the 20th century, the ability of scientists to predict earthquakes or other natural disasters is still severely limited (Gulyaeva and Arikan, 2016). Hence, in this study researcher efforts to will go deeper into natural disasters such as an earthquake, flood, and assessing the impact of natural disasters especially earthquake and flood on hospitals.

2.2. Significance of Disaster Management in Hospitals

The hospital has been defined by PAHO (2000) as “a laboratory, hotel, office building and warehouse”. The significance of hospitals and health centers is well recognized in terms of their importance in providing services to patients at any time. Indeed, hospitals are arguably powerful symbols of social progress. They are a prerequisite for stability and economic development and have symbolic social and political values that contribute to a community’s sense of security and well-being (Musani, 2008). It is crucial that hospitals remain safe and functional during and after disaster events, and it is recognized that hospitals at any size need high attention in the case of natural disasters, as they must continue patient treatment and provide care for persons injured by the event (Eybpoosh *et al*., 2011).

Hospitals are expected to be ready to play an essential role in reducing death and injury, and hospital readiness has been defined as the ability to effectively maintain hospital operations, sustain a medically safe environment, and adequately address the increased and potentially unexpected medical needs of the affected population (Yeatts *et al*. 2009).

Over the past years a number of hospitals around the world have been affected by disaster events; for instance, between 2001 and 2011, 119 natural hazard events were recorded in 25 provinces of Iran (11.9 hazards per year) that affected the primary health care centers and threatened the lives and safety of health staff. This represents 3.1% of the 3,903 natural hazard events overall that occurred in the same time period in Iran. These 119 events led to the physical damage or functional failure of 1,401 health centers, the injury or illness of 644 people, and the death of 127 health workers. Kerman, Sistan and Balouchestan and Lorestan were the provinces that experienced the highest number of adverse impacts from natural hazards on their health centers. Figure 2 demonstrates the occurrence of natural hazards in Iran between 2001 and 2011, which had an impact on its primary health care facilities.

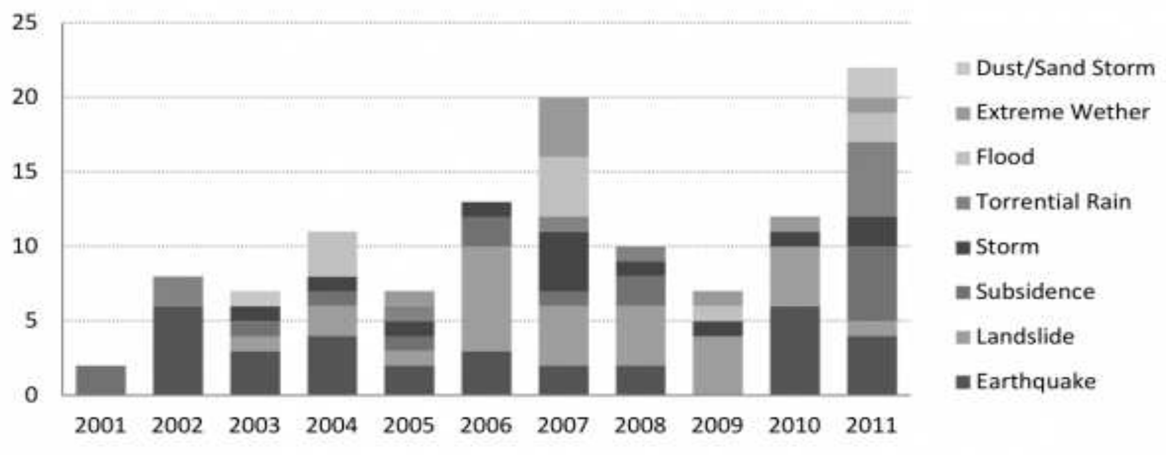

Figure 2: Occurrence of Natural Hazards with an Impact on Primary Health Care Facilities in Iran 2001-2011
(Source: Ardalan, 2013)

A key criterion for hospital readiness involves having a comprehensive disaster plan, this first begins with a comprehensive risk assessment and hazards vulnerability assessment to identify the most likely threats to a particular hospital. Readiness continues to mitigation, preparedness, response and recovery phases (Kaji, 2006). To avoid the impact of disasters on hospitals, it is vital that they have appropriate disaster management strategies to mitigate the adverse impacts. The aim of a comprehensive hospital disaster plan are to: enable the hospital to effectively manage a disaster, provide continuity of basic societal functions, minimise the physical damage to a hospital, as well as minimise loss of life, injury or illness of hospital personnel and human suffering of the persons affected (Kaji, 2006).

A comprehensive hospital disaster plan includes all hazards, all disciplines/phases, and all levels/related organizations in the disaster management process (Koeing and Schultz 2010). Nevertheless, it is important not to regard the plan as the entire essence of emergency preparedness, but rather as one essential element in a spectrum of activities (Adini *et al*. 2006). Having a disaster plan does not equal complete preparedness (Kaji and Lewis 2006); however, a comprehensive disaster plan is considered the backbone of a hospital's preparedness. One important aspect of a comprehensive disaster plan is an all-hazards approach, which refers to the consideration of any incident or event that could pose a threat to human life, property or the environment (ASTM 2009). An all-hazards approach does not mean being prepared for any and all hazards that might manifest in a particular community, including a hospital. Instead, it means that there are common needs and responses that are required in disasters, such as the need for the treatment and triage of victims that can be addressed in a general plan; this type of plan can provide the basis for responders to prepare for these types of unexpected events. The plan provides a framework for responding to various types of disaster; however, planners typically only address the kinds of disasters that might be expected to occur (Waugh, 2005).

Another aspect of a comprehensive disaster plan is to consider all phases of the disaster management cycle. An effective hospital disaster management plan must be constructed in four stages of emergency management, which are: (1) mitigation, (2) preparedness, (3) response, and (4) recovery (Adini,and *et al* 2003). For example, the hurricanes of 2004 that struck Florida provide useful insights into what can go wrong even when such an event has not been taken into account. Hurricane Charley, a weak Category 4 storm, made landfall in Charlotte County along the western coast of Florida. A regional medical center located in the area sustained significant damage to its roof and windows, resulting in rainwater infiltration into patient rooms and other medical service areas. As the storm passed through the area, the hospital lost its main power, resulting in the activation of its emergency power generators. However, the generators only had enough diesel fuel to keep the facility operating for 28 hours. A backup emergency generator and fuel tank (Nathan, 2004).

2.3. CHALLENGES FOR HOSPITALS DISASTER MANAGEMENT

In terms of the importance of hospital disaster events, there are some barriers that work against disaster managers when trying to manage such events. Yarmohammadian *et al*. (2013) state there are internal and external barriers that disaster managers must face. Some internal barriers for hospitals include; a lack of encouragement and motivation between hospital and management staff, a lack of a universal language between staff, the high cost of implementation of emergency equipment for incident events a lack of competitive atmosphere for the excellence and progress involvement of administrative managers in daily activities, also a lack of recognition amongst staff for the need for crisis management, as well as a lack of knowledge about dealing with natural disasters in hospitals amongst disaster managers (Milsten, 2000). Also there are some external barriers that disaster managers must face, such as a lack of commitment amongst managers and a lack of managers with sufficient authority to oversee the plan's implementation, the absence of statutory requirements, the involvement of different decision making authorities, a lack of appropriate administrative culture for managing crises, weak communication and coordination of crisis teams, and the lack of an emergency incident command system in the country at a higher level (Yarmohammadian *et al*., 2011).

3. RESEARCH METHODOLOGY

This research is based on secondary data analysis that aims to explain and define disaster impacts on hospitals. This study used journals, books, and databases to gather information regarding the context, the local pre-disaster availability of hospitals and health facilities, and the sudden impact of natural disasters on the hospitals. This research is a qualitative study, which was conducted by variety literature in terms of natural disasters and impact of those events on hospitals. In this study researcher concentrate on the impact of natural disasters on hospitals, hence two types of disasters such as earthquake and flood are considered. At this point, the primary data collection and analysis has not yet been completed, which will be collected by semi-structured interviews with some relevant expert views regarding hospital disaster management. Thus this qualitative research is purely adopted a qualitative data collection strategy, and consider a variety of secondary sources accessed through the Internet and academic databases.

4. THE IMPACT OF NATURAL DISASTERS ON HOSPITALS

According to the WHO (cited by Noralfishah *et al*, 2015), hospitals play critical roles in disaster events in that they provide communities with essential medical care. However, depending on the nature and impact of disasters, the demand for health care services can rapidly increase and can overwhelm the functional capacity and safety of hospitals. There are different impacts that can be seen in disaster events, such as the impairment to hospital functions, the direct impact on patients and health equipment, and the physical damage to hospital buildings (Ardalan and Schnelle, 2016). In disaster events, patient documents and medicine can be affected and it is particularly important to protect these in an incident. Also, supplying food and necessary medicine, especially in the early hours of the disaster, is crucial and must also be considered by disaster managers (Nakhaei *et al*, 2014). In particular, disasters can have two different impacts on hospitals. The first was identified by the Disease Control Priorities Project (2007) which noted a range of damage and loss,, such as the loss of health equipment, a failure in a hospital's energy resource, a lack of staff, difficulty in accessing patients' documents (for example, medical records), and issues in accessing the hospital building. For example, the earthquake that struck Mexico City in 1985 resulted in the collapse of 13 hospitals. In just three of the hospitals' buildings, 866 people died, 100 of whom were health personnel, and nearly 6,000 hospital beds were lost across the city's metropolitan facilities. Furthermore, as a result of Hurricane Mitch in 1998, the water supply systems of 23 hospitals in Honduras were damaged or destroyed, and 123 health centers were affected. Finally, Peru reported that nearly 10% of the country's health facilities suffered damage as a result of El Niño events in 1997–1998.

5. DISCUSSION

As identified, hospitals can suffer a range of damage to equipment, utility supplies, patient documentation, staff and patients through natural disaster events, and all of these impacts can decrease or prevent the treatment of injured people by the health service. For instance, the continued operation of healthcare facilities after earthquakes depends on the available utility systems as the majority are supplied from main grids and networks, such as electric power, water supply, and telecommunications. As demonstrated in Figure 3.0, a disaster can have a long-term impact; for example, there are two different types of damage to hospitals, namely direct and indirect, and the sum of these two types comprise the total cost of a disaster.

Direct damages refer to the loss of materials, hospital beds, medicines, and destroyed health equipment; thus it refers to damage that is the immediate consequence of a disaster and usually remains for a long period after a disaster event. Natural disasters can cause serious damage to health facilities, water supplies, and sewage systems, and as such, have a direct impact on the health of the population dependent on these services. In the case of structurally unsafe hospitals and health centers, natural disasters jeopardize the lives of hospital occupants and limit the capacity to provide health services to disaster victims. There are important lessons to be learned from past natural disasters. Hospital administrators must first have a clear and complete understanding of the types of disaster that can affect their facilities, specifically the magnitude and probability of an occurrence. Given these exposures, they must identify the vulnerable areas of the hospital complex, particularly those parts that provide essential support to the facility: namely, the electrical rooms, air handling equipment, fire protection systems, medical gasses, and communications. Finally, once exposures and vulnerabilities are identified, they must establish a cost-effective mitigation plan to minimize the risks.

Several methods are available to determine the optimal amount of funding to invest in order to reduce the risks posed by natural hazards. Such an investment in mitigation aims to ensure that a hospital is able to fulfill its essential role as a provider of critical care to victims following a natural disaster (Nathan, 2004). Therefore, the type and magnitude of a natural disaster determine the impact on a hospital, in terms of their water and food supplies, sewage systems, access to buildings, access to patient documentations, and medical supplies. The immediate health burden depends on the nature of the hazard. In the aftermath of a major disaster, authorities must meet extraordinary demands with resources that may not even begin to meet basic health needs, and that often have been drained by the immediate emergency response. Although disasters related to natural events may affect the transmission of pre-existing infectious disease, the imminent risk of large outbreaks in the aftermath of natural disasters is often overstated.

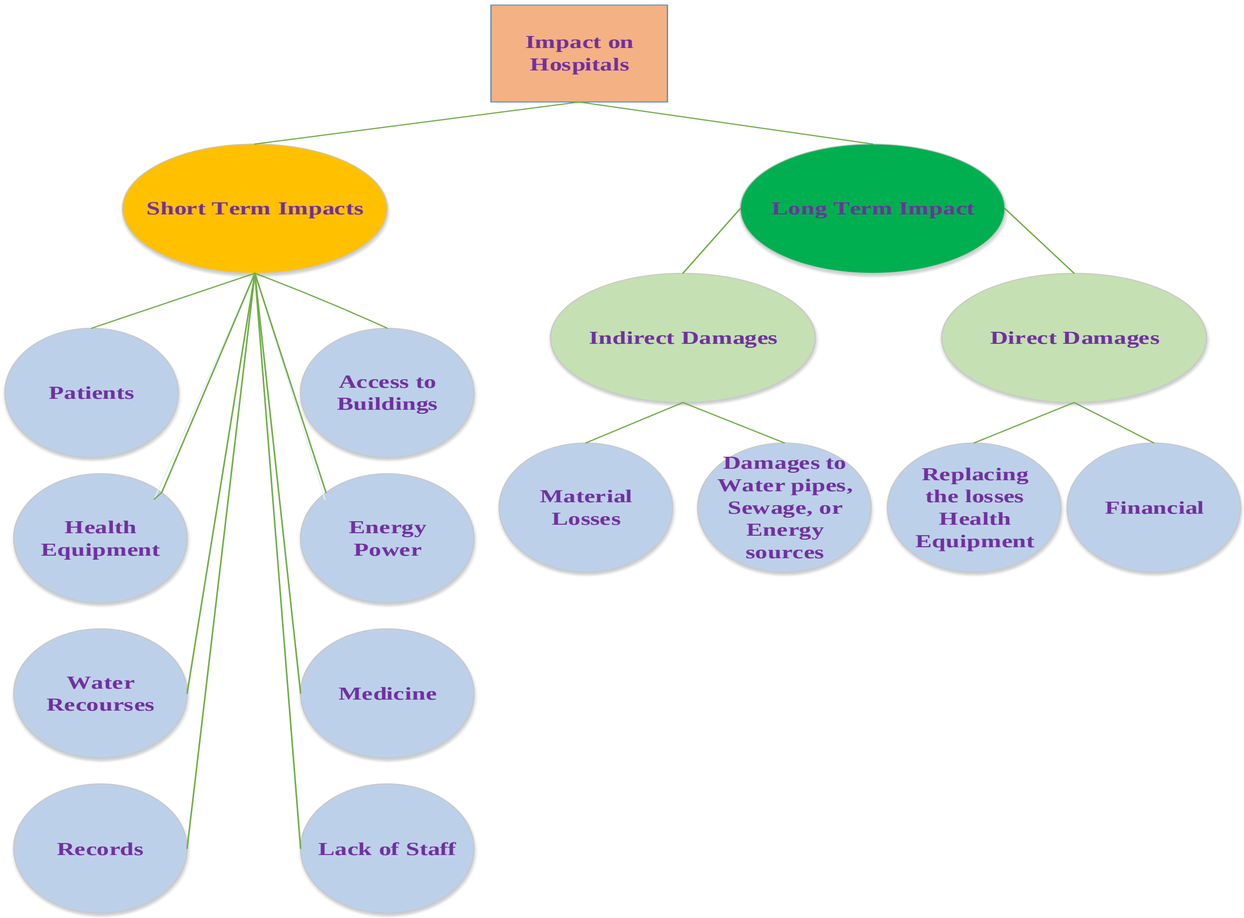

Figure 3: Summary of Impact of Disasters on Hospitals
(Source: DCPP, 2007)

6. CONCLUSIONS

Disasters are not likely to decrease in the foreseeable future; therefore, a sustained effort is needed to minimize risk by reducing vulnerability through prevention and mitigation and by increasing capacity through preparedness measures. In previous experiences, such as earthquakes, floods, or tsunamis, the importance of hospitals have been critically important. Previous strategies employed by health authorities and relief groups to reduce further morbidity and mortality following natural disasters may be helpful in similar future events; however, this must be comprehensively evaluated for each disaster plan. Due to the geographical and geological situation of these previous incidents, it could be argued that further disaster events are inevitable. Nevertheless, many lessons should be learned from previous natural disaster events and how planning could be applied to future incidents. Therefore, planning for natural disasters depends on the type and magnitude and its consequent impact on hospitals' water and food supplies, sewage systems, access to buildings, access to patients' documents, and medical supplies. The immediate health burden depends on the nature of the hazard. In the aftermath of a major disaster, authorities must meet extraordinary demands with resources that might not begin to meet even basic health needs and that often have been drained by the immediate emergency response. Disasters related to natural events may affect the transmission of pre-existing infectious disease, but the imminent risk of large outbreaks in the aftermath of natural disasters is often overstated. Therefore, comprehensive and effective disaster management is highly important for hospitals and health centers. During a disaster, it may become necessary to evacuate non-ambulant and ambulant patients; thus the response to disaster including evacuation procedures should be well established. Nevertheless, this research can contribute to the existing knowledge for managing better health centers during disasters, and mitigate the impact of natural disasters in hospitals.

7. REFERENCES

Adini, B., Goldberg, A., Laor, D., Cohen, R., and Bar-Dayan, Y. 2007. Factors that may influence the preparation of standards of procedures for dealing with mass-casualty incidents. *Prehospital and disaster medicine*, 22(03), 175-180.

Al-Dahash, H., Thayaparan, M., and Kulatunga, U. 2016. Understanding the terminologies: disaster, crisis and emergency. *Management,* 2, 1191-1200.

Alexander, D. E. 2003. *Principles of emergency planning and management:* Oxford University Press on Demand.

Ardalan A, Mowafi H, and Yousefi H. 2013. Impacts of Natural Hazards on Primary Health Care Facilities of Iran: A 10-Year Retrospective Survey. *PLOS Currents Disasters*. 2013 Jun 28 . Edition 1.

Ardalan, and Schnelle, D. D. 2016. Chapter 93 - Introduction to Natural Disasters A2 - Ciottone, Gregory R Ciottone's Disaster Medicine.2nd ed. Philadelphia: Elsevier.

Bosher, L., and Dainty, A. 2011. Disaster risk reduction and 'built-in'resilience: towards overarching principles for construction practice. *Disasters,* 35(1), 1-18.

Burnham, E, and Gilbert M C. R. 2013. *John Hopkins and the international federation of Red Cross and Red Crescent societies Public Health Guide for Emergencie*s. Retrieved from www.jhsph.edu/research/.../Public_Health_Guide_for_Emergencies [Assessed date 28.05.2016]

Eybpoosh, M., Dikmen, I., and Talat Birgonul, M. 2011. Identification of risk paths in international construction projects using structural equation modeling. *Journal of Construction Engineering and Management*, 137(12), 1164-1175.

Gulyaeva, T. L., Arikan, F., and Stanislawska, I. 2017. Earthquake aftereffects in the Equatorial Ionization Anomaly region under geomagnetic quiet and storm conditions. *Advances in Space Research*. 60(2), 406-418

Huder, R. C. 2013. *Disaster operations and decision making:* John Wiley and Sons. New Jersy

Kaji, A. H. L., Roger J, and Lewis, R. J. 2006. Hospital disaster preparedness in Los Angeles County. *Academic emergency medicine*, 13(11), 1198-1203.

Kenny, C. 2012. Disaster risk reduction in developing countries: costs, benefits and institutions. *Disasters*, 36(4), 559-588.

Koenig, K., and Schultz, C. H. 2010. *Disaster medicine*: Cambridge, UK: Cambridge University Press.

Lin Moe, T., and Pathranarakul, P. 2006. An integrated approach to natural disaster management: public project management and its critical success factors. *Disaster Prevention and Management: An International Journal, 15*(3), 396-413.

McEntire, D. A. 2014. *Disaster response and recovery: Strategies and tactics for resilience*: John Wiley and Sons. New Jersey.

Milsten, A. 2000. Hospital responses to acute-onset disasters: a review. *Prehospital and disaster medicine*, 15(01), 40-53.

Musani, A., and Shaikh, I. A. 2008. The humanitarian consequences and actions in the Eastern Mediterranean Region over the last 60 years--a health perspective. *Eastern Mediterranean Health Journal*, 14(S1), A150-A150.

Nathan C. Gould., 2004. Available from: https://www.irmi.com/articles/exper commentary/understanding-the-vulnerability-of-hospitals-to-natural-disasters [Accessed 15 February 2017].

Nakhaei, M., HamidReza, K., GholamReza, M., MohammadAli, H., and Zohreh, P.-Y. 2014. Health management in past disasters in Iran: A qualitative study. *Qualitative research*, 9, 10.

Noralfishah, S., Thayaparan, M., Haidaliza, M., and Kulatunga, U. 2015. The impact of the flood disaster in Malaysia: a case study on public hospitals. Special Themed Session: Cities, Infrastructure and Cascading Natural Disasters, 28-33.

Preparedness, P. A. H. O. E., and Program, D. R. C. 2000. *Principles of Disaster Mitigation in Health Facilities*: Pan American Health Org.USA

Rathore, F. A., and Gosney, J. 2015. *Rehabilitation lessons from the 2005 Pakistan earthquake and others since–looking back and ahead*. J Pak Med Assoc, 65, 1036-1038.

Salamati, N., Kulatunga, U., and Thayaparan, M. (2016). The Importance of Disaster Management and Impact of it into Hospitals. Paper presented at the *SPARC 2016*, Media city UK.

Shaluf, I. M. 2007. Disaster types. Disaster Prevention and Management: *An International Journal*, 16(5), 704-717.

Tomasini, R. M., and Van Wassenhove, L. N. 2004. Pan-American health organization's humanitarian supply management system: de-politicization of the humanitarian supply chain by creating accountability. *Journal of public procurement*, 4(3), 437.

Yarmohammadian, M. H., Atighechian, G., Shams, L., and Haghshenas, A. 2011. Are hospitals ready to response to disasters? Challenges, opportunities and strategies of Hospital Emergency Incident Command System (HEICS). *Journal of Research in Medical Sciences*, 16(8), 1070-1077

Yeatts, D. J., Barbera, J. A., and Macintyre, A. G. 2009. Challenge of hospital emergency preparedness: analysis and recommendations. *Disaster Medicine and Public Health Preparedness*, 3(S1), S74-S82.

Waugh, W. L. 2005. Terrorism and the all-hazards model. *Journal of Emergency Management*, 2(1), 8-10.

WHO, G. 2011. Guidelines for drinking-water quality. *World Health Organization*, 216, 303-304.

THROUGH-LIFE RISK MANAGEMENT IN MEGA PROJECTS

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ABSTRACT

Mega Projects play a significant role in the UK construction industry. They provide infrastructure, business and employment opportunities for the nation. They are complex, and involve considerably high cost, and risk. Therefore, through-life risk management practices are considered as a mandatory consideration in mega projects. These risks arise in externally (political, economic, social, technological, environmental, legal, etc.) and/or internally (project, stakeholders, etc.), and the influence of such risks leads to a substantial cost overruns. Therefore, such risks need to be managed efficiently to endorse the project success. This study investigates the through-life risk management strategies that are adopted in the UK Mega Projects.

A literature review, four semi-structured interviews and a structured online questionnaire survey were the methods used to collect data. Interview data was analysed through NVivo and appropriate themes were developed. This was compared with the survey findings and conclusions were drawn accordingly. The findings explain that through-life risk management is a mandatory requirement in mega projects, and design and economic risk are the two most significant project risks that need to be addressed in advance. However environmental risks also play an important pre-requisite role in mega projects. Findings further explain risk register as a mandatory requirement for mega projects, which provides the opportunity for the project to keep track of all risk whether they have happened, will happened or currently happen.

Keywords: *Through-life Risk Management; Types of Risks; Strategy; Mega Projects; United Kingdom.*

1. INTRODUCTION

Mega projects are highly complex ventures, which usually take several years to design and construct. 'Mega' can be a scientific and technical unit of measurement which would be a million, so in economic terms, it would be a million-dollar (or euro, pound etc) project (Flyvbjerg, 2014). Literature explains the cost of mega projects range from £100M to over a billion pounds, due to their complexity, involvement of several public-private stakeholders, and the impact of such projects on the wider society (Oliomogbe and Smith, 2013). Mega projects are ‘privileged particles of the development process’, they are usually trait making, which means that they are intended to alter the structure of society unlike smaller and original projects that do not have an impact on the society at a wider spectrum (Hirschman, 1967 cited in Flyvbjerg, 2014). Mega projects contribute to 8% of the global gross domestic product. Flyvbjerg (2014) explains that cost of a few of the biggest mega projects in the world would dwarf most of the other economic and investment figure.

Mega projects play a pivotal part in the UK construction industry. They create opportunities such as absorbing the blue-chip clients/ companies into the UK, which would in turn draw investment for British lead schemes. For example, the London 2012 Olympics project had a budget of under £9 Billion pounds. PricewaterhouseCoopers (PwC) have declared that around $1.5 trillion of the $78 Trillion global investment fund for capital projects and infrastructure up to 2025 is intended for the UK (McClelland, 2015). The UK government intends to invest on megaprojects as agreed in their National Infrastructure Delivery plan 2016-2021. The plan further outlines that over £100 billion is dedicated to 2020-21, which is part of a £483 billion project pipeline. The government's intention was to set a robust foundation for better infrastructure, productive economy and improved society for many years to come. The UK has been considered for how mega projects

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are being delivered in a 'radically new way', and further adds that the United States and several European cities are 'watching' and 'learning' (McClelland, 2015).

There are several mega projects running across the UK and many of them are funded through the central Government. The risk attached to those projects are multifaceted and project specific. However, when it comes to mega projects the project itself is complex and cost/value driven. Therefore, correct risk management strategies should be implemented within these projects to minimise the damage (time, cost overruns, poor quality) as much as possible. There is plethora of literature to discuss the risk management in construction projects; however, limited attention has been paid on mega projects. Therefore, this study aims to bridge this gap by identifying the through life risk management strategies of mega projects.

The first section of the paper explains the nature and characteristics of mega projects, and the second section discusses the risk management approach in specific to mega projects. Having analysed the findings of interviews and surveys, the third section illustrate the significant risks associated with mega projects and adopted risk management strategies.

2. RESEARCH METHOD

The study adopted a multi-method approach to collecting data. A detailed literature review was undertaken to identify characteristics of mega projects and also the principles and practices of risk management in specific to construction context. An online questionnaire survey was conducted among the construction industry professionals to identify the most significant risks and the strategies for managing such risks in mega projects. Moreover, four semi-structured interviews were conducted among the selected construction industry professionals who are experienced in mega projects. Those interviews were used to validate the survey findings and also further helped to carry out insightful discussions on RM in mega projects. NVivo-11 was used to analyse the interview data.

3. NATURE AND CHARACTERISTICS OF MEGA PROJECTS

Mega projects are defined as those which require spending over and above department expenditure limits, require primary legalisation and are innovative or contentious (GOV.UK, 2016). The US Federal Highway Administration defines megaprojects as major infrastructure projects that cost more than US$1 billion (cited Flyvbjerg, 2001). Stoddart-Stones (1988) noted that mega projects belong to a complex management structure and can have a value of over £150M. In general, mega projects draw high levels of public and political interests as because they can have a considerable direct impact on the community, environment and budget (Flyvbjerg, 2001). It is noteworthy that politics play a key role in mega projects. The mega projects consider within this research investigation is limited to a project value over £100M.

Two of remarkable characteristics of mega projects are the high cost of construction and its associated risks. Moreover, these projects take longer time to deliver the end-product, as mainly because of finance arrangements, stakeholder influence/interest on project goals. Oliomogbe and Smith (2013) identify the 'Value in Megaprojects', construction cost, size, poor performance, risk and uncertainty as key characteristics when compared to other construction projects. In fact, these projects are highly complex, and resource intensive. They usually have social, environment and political influences, as many mega projects are of high value, the government and local councils usually play a pivotal part on such projects. Supportively, Othman (2013 cited Ruuska *et al*, 2009), explains that mega projects are usually initiated due to the impact of a wider socio, political movement. Clients of mega projects are often a government or public sector organisation, however mega projects are rarely delivered by a single entity. The designed lifespan of the product/facility is lengthy and the product is expected to be benefited by the public as most of the government funding is based on tax payers' money.

4. RISK MANAGEMENT PRACTICES IN MEGA PROJECTS

'A chance of something unpleasant will happen' is considered as 'risk' (Hopkin, 2013). In the context of construction, it is necessary to identify those likely risks as early as possible to prevent cost-time overruns. The identified risks need to be managed through appropriate mechanisms. A formalized approach must be planned and the 'nature of risk' should be managed appropriately (Hopkin, 2013) as some risks will provide rewards to the bearers. Risk identification is a key to success and should be accomplished before the project initiation and continued throughout the life cycle of the project (Department of Energy Project Management, 2005).

Risk identification can be done through analysing the historical data of similar scenarios/projects to perceive what risks, where associated, and how those risks were dealt with and if the risks where not resolved how can they be avoided in the upcoming task. Supportively, MITRE (2013) explains that historical information from similar government programs can provide valuable insight into future risks. The quicker the risks are identified, the quicker the actions can be put in place to minimise or manage the risks (Department of Energy Project Management, 2005).

Risk management refers to the measures put in place to warrant the best solution that occurs after the event has happened and in most cases, predict the events that might happen and put actions to limit those events. ISO 31000:2009 defines risk management as ‘a coordinated set of activities and methods that are used to direct an organization and to control the many risks that can affect its ability to achieve objectives’ (British Standards Institution, 2009). Risk management follows key phases, which are, planning, identification, analysis (qualitative, quantitative), risk response planning, risk monitoring and control (Hilson, 2016). When the risks are identified, the process can begin to manage those risks. Risk management is an expanding field which literature has revealed that it can be used not just for protecting against loss but to accomplish larger rewards (Dey, 2012). Risk management cannot occur without risk, as risk management originates from the objectives of risk. Then the capability of that individual or organisation to successfully override those reservations of completing tasks with associated risk will have a direct effect on the ability to flourish in the task which is being completed.

Hilson (2016) identified risks as belonging to three separate categories namely, highly rated, lowly rated and risks that can only be seen in the programme, and stated that they can be managed separately. Highly rated risks related to individual projects can be those, which have complex technology, or a difficult location, Department of Energy Project Management (2005) stated that these risks would be best managed at a project level; however, programme and portfolio managers should recognise them as well. The risks which were not rated highly (lowly rated) involved low skilled staff, unreliable supplier and can appear in numerous places rather than on project. Those risks where best managed at programme or portfolio levels instead of directly with individual projects. For those risks that can be seen on the programme, these risks involve wider economy, or environment, and are best dealt within the programme. If the organisation or individual fail to identify the risks, which inhibit reaching the objectives, then these non-identified risks will become non-manageable. If this occurs, this will lead to consequences originating from the risk to be unexpected.

Once the risk has been identified, the individual or organisation will attempt to figure out why those certain risks will occur. Risk assessment includes identifying risks and the ability to rate them to establish the significant risks facing the organisation or project (Hopkin, 2012). A significant step is select whether the risks, which have been identified, shall be evaluated at the inherited level or the residual level. Inherent risk occurs without taking into consideration of the controls that are currently in place. The British Standard BS 31100 (2011) explains that risk assessment should be completed at inherent and residual level.

There are various techniques used in risk assessment, and these techniques should relate to how that certain individual or organisation interacts. For example, if the organisations were used to working in a group, workshops would be beneficial to them, unlike organisations that do not regularly work in groups. Specific actions will be undertaken to control the probability of the risks occurring or if the risk does happen what actions will be taken to minimise the effect of the risk. Risk has four treatment mechanisms in which they can be managed, namely, avoidance, reduction, transfer and acceptance (Hilson, 2016; Spacey, 2010).

The Institute of Risk Management (2016) states that risk treatment can be accomplished by for distinctive levels of authority, leadership, senior management and support level. At the leadership level the individual would ensure that the companies are following the correct protocol when risk arises, additionally promote risk treatment strategies. The senior level, the organisations methods to risk treatment are monitored and any proposals are put forward. Management level overseas the quality of risk monitoring and intervenes when certain problems arise and controls the management of the risks in line with the companies’ risk strategies. Finally, the support level explains various benefits of risk treatments and their suitability to a different risk.

When considering mega projects, certain risks will arise due to the size and the cost of the project. Across the year's construction of mega-projects has offered consistent problems within periods, for instance cost overruns, delays, revenues coming up short and in some cases technical failure (de Bruijn and Leijten, 2008). Often the projects are led by planners and managers without the experience, and who will be changed throughout the lifecycle of the project, as some projects can last more than a decade. For example, the HS2 that project is expected to be fully operational by 2030 (BBC, 2016) which is about 12 years of construction. These changes of staff due to the time of the projects can weaken the leadership and cause a breakdown of communication of the project, throughout the whole structure of the organisation.

The major significant risk is cost, these projects are of high value and be more than a billion dollars as stated above. If these projects are not monitored efficiently then exceeding of the budget is more than likely. Certain projects are most likely to go over budget than others are, for example, rail projects are likely to go over budget by 45%, bridges and tunnels have an average of 35% of cost overrun and road projects come up to a figure of 20% (Garemo *et al*, 2015). Flyvbjerg *et al.*, (2003) in their study with 258 infrastructure projects that most common findings in nine out of the ten cases was that costs on mega-projects where undervalued. Furthermore, time overruns occur, this is a risk alone as this can stop the organisation from meeting key deadlines dates which have a rollover effect and in turn can cause a cost overrun. Time overruns occur due to the complexity of the project and unplanned events are not often accounted for, additionally misinformation about schedules can play a pivotal part in time overruns (Flyvbjerg, 2014).

Flyvbjerg, (2014) stated that the project scope or levels of ambition can change drastically over a period. This is a negative risk as for a project to be successful and be completed to client's satisfaction, which would expect levels of ambition to be high always and small amount of changes over the period of the project, and if there are changes there shouldn't be major alterations to the scope. As constant changes, can cause confusion on the project, which could lead to problems such as delay and cost. Complexity is one of the main characteristics of mega-projects; this characteristic brings about certain risks when undertaking projects. de Bruijn and Leijten, (2008) categorised complexity of a project into two sections, technical complexity and social complexity.

If there is full detailed design whilst work is commencing, there is less likely chance of problems being maturing. However, if the design is too complex this can be a negative point, as if the project team lacks experience with the type of project, which is being developed, problems can arise and they would not be able to manage the problem. If the project is less robust, the lack of design can bring about less predictable actions, which would affect the manageability (de Bruijn and Leijten, 2008).

Advances in technology have allowed construction sites to be safer on site and reduce any risk once the work has started, and has allowed buildings to become more complex. For instance, over the recent years BIM is being elemental in the construction industry 'with the correct use of BIM, eliminating risks is a much easier process. It allows us to consider the future and experience how the building will work before completion, thus eliminating or reducing risks' (Piff, 2013).

5. RESULTS AND DISCUSSION

The piloted online questionnaire was sent out to 282 construction industry professionals and 74 of them responded after two follow-ups. The respondents are from architecture (12%), contractor (16%), project management (20%), quantity surveying (22.7%), risk management (6.7%), and other which includes BIM managers, portfolio managers etc (22.7%), and majority (56.8%) of them are having more than 5 years of professional experience. Further analysis explains that 21.9% works in consultancy, 47.9% in contracting, 19.2% for client and 12.3% in other businesses. The UK contracting sector is the largest in the construction industry as it produces 2 million jobs and 234 thousand business annually (GOV.UK, 2013) which the majority of respondents are represented.

The respondents are currently working in several sectors including commercial (23%), industrial (27%), civil infrastructure (12.2%), residential (16.2%) and other (21.6% in oil and gas, services etc) and 60.8% works in mega projects (cost of construction exceeds £100M). Moreover, respondents have identified following risks from their projects.

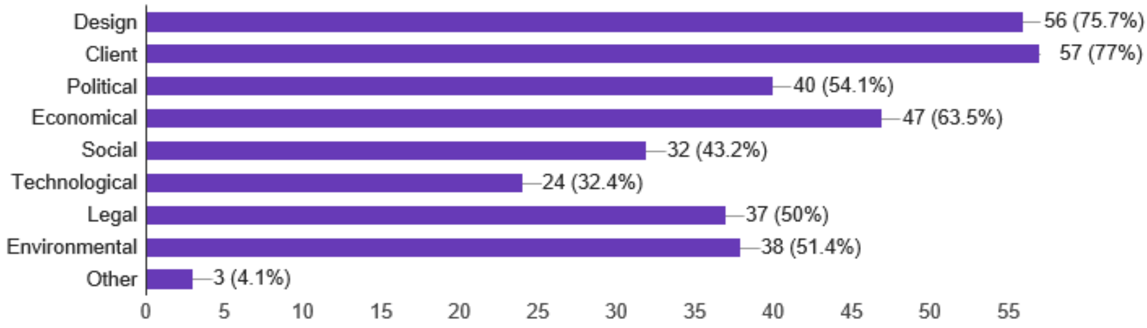

Figure 1: Types of Construction Risks in Mega Projects

The respondents agreed that 'design' and 'client' risks are the significant risks that will have an adverse effect on the project. One respondent further explained that "design can be viewed as the biggest risk as if you get the wrong design it can alter the whole project and in turn affect cost". Economic risk (cost) was the third highest (63.5%), which shows the importance of the cost when considering project through life. Literature reveals cost - time overruns as the significant risks in construction context. 77% of projects have considered a risk management strategy in place however 13.5% of projects haven't had any of the risk management (RM) strategies. The literature reveals "no construction project is risk free and risk can be managed, minimised, shared, transferred, or accepted it cannot be ignored" (Latham, 1994).

The survey findings further explain 68.5% of respondents have experience in working on mega projects. Having considered the RM strategies that in place those projects one respondents explained that they adopted "fast track design and build, had little or no risk at all, however risk did arise from design changes and mechanical and electrical engineering". Another respondent noted that the "risk management strategy in place would be determined on the level and type of risks, which have been imposed on the contractor by the contract". Majority of them agreed that the contract should share the risk this would allow the parties to manage and mitigate the risks efficiently". The survey findings overview the construction risks in general, and also likely risks in mega context. To dig the tunnel on to the risk in mega projects, the study further carried out four detailed interviews with two quantity surveyors, one civil engineer and one design manager who are having mature experience in mega projects.

The main characteristic that all interviewees shared on mega projects is that "mega projects tend to be of high value". Additionally, two of the participants gave examples of work that they are involved in or will be involved in to describe a mega project this included the Liverpool Royal hospital, which is worth £500 million, and the Manchester Airport, which will also be worth around £500 million, and the monthly valuations worth approximately £20million. Furthermore, they explained that "mega projects are not a long duration in terms of construction, they can be 2-5 years. Adding on that mega projects might take a short or long time to construct but the projects can last a long time that is their purpose, such as hospital, transports". Moreover, they agreed that mega projects are "highly complex ventures" and 'complexity' is one of key characteristics that brings risk to project stakeholders. They further mentioned that the different partnerships/stakeholders and their different interest and influence on project goals also a key characteristic when it comes to mega projects.

When evaluating the risks in mega projects all interviewees agreed that "design creates a significant risk". Design was an important risk to consider as if the design is incorrect or you do not follow the design, then this could fail the whole project, leading to more cost. Moreover, they perceived that cost is an important element as that what makes the project 'tick over' without money the project would happen in the first place. The two quantity surveying participants viewed economy as very important, some of the participants referred to 'Brexit' when discussing the economic risk as you are never 100% what can influence the cost. The third risk that the participants viewed as high/significant was legal risk. Legal risk was not one of the significant risk found in the literature review or in fact considered a risk, and half of the participants in the questionnaire considered legal risk considered as a risk to a project. Between the interviewees environmental risk was high and significant as they viewed that legal regulations that must be followed before construction is started and throughout the construction.

All of the interviewees participated in this study concluded that risk management was pivotal in a mega project. The main reasons were that having an effective risk management strategy in place would benefit the parties involved in the project, over the life of the project. Risk must be eliminated and efficiently managed as time and costs of the project can easily escalate. One of the key risks that must be managed is health and safety, which is pivotal to a successful project. Additionally, risk management strategies could depend on the project value as, the value of the project increase the project risk also increases.

Risk strategies as identified in the data is that they need to be identified analysed and the risks should be treated as similar strategy to that of the ISO 31000 (2009). As well as having the main risk management strategy within the project, communication is very valuable as this gives the opportunity for different departments and/or professions to raise risk that others could have missed out on or did not recognise as they do not have previous experience with certain risks. Communication is granted through the project performing meetings at regular intervals so that risks can be identified, analysed and mitigated. Three out of the four interviewees noted the importance of a risk register.

Risk management strategy provides the opportunity for the project to keep track of all risk whether they have happened, will happened or currently happen. During meetings at regular intervals, within the meeting the individuals would refer back to the risk register. It is important that all risk is recorded no matter how small or big the risk is, as every small risk has the potential to develop to a major risk. Additionally, motivation of staff was important, as if the staff is motivated they will carry the jobs professionally and diligently and in turn reduce risk. One of the participants stated that to make sure a mega project is successful participant suggested that different leaders are introduced at different points of the project, as if they have experience with certain parts of a project, risk will be reduced. This is an important statement that the research analysed, as if you have one leader throughout one mega project, who probably has not dealt with certain aspects of the project it would be advised to bring another person in who has experience with that point of project, risk can arise if the leader lacks experience to deal with certain risks.

Two of the interviewees agreed that early stages of the project are vital if risk management is to play a key part in the client's investment. 'Earlier the better' as putting the correct systems in the first place will ensure the project will run efficiently, how the project will be run, how to deal with risks if that is all managed in the beginning they will be no need to panic when a risk does arise or not know how to deal with a new circumstance within the project.

Out of the two interviewees who agreed that earlier the better, one of them did state that risk management is vital throughout the whole process of the project. This was stated by the other half of the participants who mentioned that risk management plays a part in the beginining, middle and end of the project. Participants agreed that it was important as you always have to monitor risk there is not a point where risk management is pivotal as you can never be certain when the risk will arise. The recurring theme was that risk management is a process that occurs throughout the project life cycle, hence one cannot choose only a specific point to concentrate on, as this can lead to the ignoring of at other points of the project, and risk can arise when they are least expected.

6. CONCLUSIONS AND RECOMMENDATIONS

Mega projects can be defined as projects that are complicated, worth high value and can affect the broader public. Mega projects have the effect of creating many jobs during construction and after the construction has been completed. Mega projects are important to society as they have contributed to the construction of infrastructure, commercial and healthcare establishments. Main characteristics of mega projects involve high value, predominately medium – long duration of construction, complex design, and the large participation of stakeholders involved.

The risks that are associated with mega projects include political, economic, social, technology, legal and environment. Political risks related to mega projects is that when political acts affect construction, as recently the 'Brexit' vote, can cast doubt on future projects, or projects which are currently undergoing. Major economic risk with mega projects is the budget, as stated by Garemo *et al* (2015) 45% of rail projects are likely to go over budget. As in this study it has stated that the HS2 has increased budget since the first budget was revealed. In construction, cost is major factor to consider and it was of the elements in a project that has to be managed efficiently or cost can spiral out of control. Social risk is not one of the significant problems but can still manage to cause major risk to a project, for example through public demonstrations. Technological risk is probably the least significant risk taking into consideration form the literature review, questionnaires and interviews. However, the construction industry is at risk to fall further behind in technology if they do invest more money into technology. Taking into consideration the data analysis, legal risk is not a significant risk but it is still an important risk to consider when undertaken projects. This is due to certain changes in law having an impact on construction process and products. Furthermore, environmental risk concerns all aspects of life, and it is no different in construction. There is a high environmental risk as found in the data analysis and literature review. What is worse is that there have been less investments in the solutions that can help with the environment, as reported by Anders *et al* (2011) global investment is down, and this could be important when reducing CO_2 emissions.

Design is an important risk to monitor due to the fact that if the design is wrong or not followed accordingly this can in turn increase the cost of the project. Cost is one of the significant aspects to consider which can determine a projects success, as costs controls the project. If costs are not properly managed at the beginning of the project this can cause further problems later on in the project.

Due to mega projects having risks, risk management strategies must be put in place to minimise the effects of this risks. As found in the literature review and the data analysis the best method of risk management is to first identify the risk, analyse the risk and mitigate the risk. Different construction projects will interpret that method the way they see best fits to their objectives.

RM is an important consideration for every project. The market is highly driven for mega sector and massive investments. Managing risk in mega projects will positively contributes towards the sustainability agenda (social, environmental and economic). Therefore, what is new is the policy level implications and continuous review of risks in mega projects. Where the service is complex, where there are many interdependencies and interfaces, or where the risks are high, then a collaborative approach should be considered. In this sense the new approaches such as BIM should be much better integrated in to the RM process in mega projects.

7. REFERENCES

British Broadcasting Corporation, 2016. *What do we know about HS2? BBC UK* [Online]. Available from: http://www.bbc.co.uk/news/uk-16473296 [Accessed 29 Jan. 2017].

British Standards Institution, 2009. *British Standards Institution, BS 31000:2009: Risk Management: Principles and Guidelines*, British Standards Institution, London.

British Standards Institution, 2011. *British Standards Institution, BS 31100:2011: Risk Management: Code of Practice and Guidance for the Implementation of BS ISO 31000*, British Standards Institution, London.

De Bruijn, H. and Leijten, M., 2008. *Management characteristics of mega-projects. Decision making on megaprojects: Cost-benefit analysis, planning and innovation*, Edward Elgar Publishing Limited, USA. 23-39.

Dey, P. K. 2012. Project risk management using multiple criteria decision-making technique and decision tree analysis: A case study of Indian oil refinery. *Production Planning and Control*, 23(12), 903–921.

Department of Energy Project Management. 2005. *The Owner's Role in Project Risk Management*, National Academies Press, USA.

Flyvbjerg, B. 2001. *What is a Megaproject?* [Online]. Available from: http://flyvbjerg.plan.aau.dk/whatisamegaproject.php [Accessed 22 Jan. 2017].

Flyvbjerg, B., Bruzelius, N. and Rothengatter, W. 2003. *Megaprojects and risk: An anatomy of ambition*. Cambridge University Press, UK

Flyvbjerg, B. 2014. What you should Know about Megaprojects and why: An Overview. *Project Management Journal*, 45(2), 6-19.

GOV.UK, 2016. *Major Projects Authority*. [Online]. Available from: https://www.gov.uk/government/groups/major-projects-authority [Accessed 30 Jan. 2017].

Hilson, D. 2016. *The Risk Management Handbook: A Practical Guide to Managing the Multiple Dimensions of Risk.* London, United Kingdom: Kogan Page.

Hopkin, P. 2012. *Fundamentals of Risk Management: Understanding, Evaluating, and Implementing Effective Risk Management.* Philadelphia: Kogan Page.

Hopkin, P. 2013. *Risk Management*. London: Kogan Page.

Latham, S.M., 1994. *Constructing the team*. London: HM Stationery Office.

McClelland, J. 2015. *UK Megaprojects Project Management*. [Online]. Available from: http://www.raconteur.net/business/britains-most-successful-megaprojects [Accessed 24 Jan. 2017].

MITRE Systems Engineering Practice Office. 2013. *Risk Management Toolkit*, [Online]. Available from: http://www2.mitre.org/work/sepo/toolkits/risk/ [Accessed o 2nd Feb 2017]

Oliomogbe, G. Smith, N. 2013. Value in Megaprojects. *Organisation, Technology and Management in construction*, 4, 617-624.

Othman, A.A.E. 2013, Challenges of mega construction projects in developing countries, *Organisation*, *Technology and Management in construction*, 5(1), 730-746.

Palter, R., Matzinger, S. and Garemo, N. 2015. *Megaprojects: The Good, the Bad, and the Better*. [Online] Available from: http://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/megaprojects-the-good-the-bad-and-the-better [Accessed 29 Jan. 2017].

Piff, D. 2013. *BIM: The Risk Eliminator*. [Online] Available from: https://www.fgould.com/uk-europe/articles/bim-risk-eliminator/ [Accessed 31 Jan. 2017].

Spacey, J. 2010. *5 Types of Risk Treatment*. [Online] Available from: http://simplicable.com/new/risk-treatment [Accessed 19 Feb. 2017].

Stoddart-Stones, R. 1988, Development of project management systems for major projects, *International Journal of Project Management*, 6, 34-38.

TRIZ-DR MODEL FOR DISPUTE RESOLUTION IN CONSTRUCTION INDUSTRY

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ABSTRACT

Conflicts and disputes are inevitable in the construction industry. This is due to the complex nature and the involvement of so many parties along the contractual chain, adversarial relationships, uneven risk allocation and uneven bargaining power. Different formal and informal Dispute Resolution (DR) strategies are currently being practiced in construction industry aimed at resolving disputes as effective as possible. But the major drawback of these strategies is the lack of innovativeness generated within their processes. In this background, significance of an inventive dispute resolution approach is emphasised.

As an inventive problem solving tool, TRIZ methodology has become famous in various fields such as Engineering, Manufacturing and Information Technology. TRIZ is primarily about solving technical and physical problems, but is now being used in solving many problems or situations. Hence, this study aims to develop TRIZ-DR model to resolve disputes in construction industry.

Accordingly, a mixed methods research approach was followed to achieve the research aim. A comprehensive literature review followed by semi structured interviews with seven subject matter experts were used to investigate the common construction disputes, existing dispute resolution strategies and their drawbacks, applicability of TRIZ based approach for construction dispute resolution and implantation procedure. The collected data were then analysed using code based content analysis and statistical mode in developing the TRIZ-DR model. The four phase model is a systematic procedure of abstracting problem, relating to TRIZ-DR matrix, interpretation, suggesting a solution, checking the feasibility of the solution and implementation to be followed at each phase. Therefore, this research offers a TRIZ-DR model to enhance inventiveness in construction dispute resolution, hence providing an effective dispute resolving mechanism.

Keywords: *Dispute Resolution; Inventive Problem Solving; TRIZ Methodology; TRIZ-DR (TRIZ-Dispute Resolution) Model.*

1. INTRODUCTION

Construction projects are often criticised for its intrinsically hazardous and complicated process. Complex construction can often result in complex disputes, which predominantly arise from the difficulty and magnitude of the work, multiple prime contracting parties, poorly prepared or executed contract documents, inadequate planning, financial issues, and communication problems (Harmon, 2003). Therefore, it is necessary and useful to avoidable from necessary claims; and also to minimize disputes arising from unresolved conflict and claims in construction projects (Kumaraswamy, 1997) since the success of a project depends on the way an organization approaches problems and disputes (Danuri *et al.*, 2012).

As Cheung and Suen (2002) stated due to differences in perception and frequency of conflicting goals among partners to a project, disputes in the construction project environment are inevitable. If construction disputes are not resolved in a timely manner, they tend to drag on and escalate causing project delays, lead to claims, require litigation proceedings for resolution, and ultimately destroy business relationships (Cheung and Suen, 2002).

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There is a growing awareness in the construction industry to adopt dispute resolution techniques that can reduce the risk of disputes occurring and may prevent disputes escalating into costly formal resolution procedures (Danuri *et al.*, 2012). The importance of inventive systematic approach for dispute resolution is highlighted in this background. As a systematic inventive problem solving tool, TRIZ methodology allows finding innovative solutions to the disputes by identifying with precision the root cause of the problems (Cabrera and Li, 2014). Identifying the zones of conflict before applying the tools of TRIZ helps practitioners understand the conflict better, simplifies problem solving and can lead directly to a solution (Domb, 2015). The overall aim of TRIZ has been to construct a problem definition and solving process that enhances innovation and incremental improvement of final outcome (Stratton and Mann, 2003).

The paper stucture begins with an introduction to the study and followed by a literature review on common construction disputes and TRIZ method in section 2. Section 3 presents the research methodology and section 4 presents the TRIZ-DR model developed for dispute resolution. The final section summarises conclusions derived from the research findings and present recommendations.

2. LITERATURE REVIEW

2.1. CONSTRUCTION DISPUTES

The “Disputes may arise from different perceptions as to the legitimacy and/or the quantum of the claim” (Kumaraswamy, 1997). Construction disputes are the major hindrance for the performance of construction industry (De Alwis *et al.*, 2016). Further to the authors, it is still difficult to eliminate disputes in construction projects although the number of attempts have taken to avoid disputes while serving its own purposes.

Though the nature of disputes may vary, some disputes are common in every project irrespective of its nature. According to Assaf *et al.* (1995) contractual dispute is the most common dispute in the construction industry. Furthermore, Cheung and Yeung (1998) stated that time delays and contractual disputes has a huge impact on the construction industry. In addition, Wall (1998) mentioned that delayed payments and erroneous documents even have become vital there.

Relationship between contractor-subcontractor and contractor-employer cause for critical disputes in a construction project (Cheung and Yeung, 1998). Kumaraswamy (1997) identified human relationships as one of the most vulnerable elements which results in construction disputes. The disagreements due to quantity evaluations also laid the foundation for serious construction disputes in the construction industry (Kumaraswamy,1997). Employer has a great responsibility of facilitating funds for the construction and if not it ultimately results a dispute (Fenn *et al.*, 1997). All above facts supported that delayed payments and unwanted interference by the employer result in construction disputes.

Further to the authors, the different types of disputes can be; Contractual disputes, Management related disputes; Time Delays; Material delivery delays; Delayed Payments; Construction defects; Document errors; Contractor – Subcontractor relationship; Contractor - Employer relationship; Quantity measurement and evaluation; Termination; Lack of communication; Contractor’s poor financial control; Employer interference; Frequent and late changes to design and the External factors such as Market, Political and Weather. Resolving above stated disputes in an effective manner is crucial to enhance the efficiency of construction project outcome.

2.2. DISPUTE RESOLUTION

Construction industry is characterized to be antagonistic and confrontational. Hence, disputes have become increasingly common in the construction industry. Chong and Zin (2012) stated that disputes should be resolved in the earliest possible stages of dispute resolution. Cui (2014) further reviewed that if any dispute which is not resolved promptly, then it may escalate, and ultimately require litigation proceedings, which can be extremely costly for the parties concerned.

Cheung *et al.* (2000) highlighted that dispute resolution in construction industry is crucial and topical as there is a growing concern. Considering the increasing complexity of construction projects and the economic environments within which they are being procured, there is a need to obtain an enriched understanding of the underlying conditions that contribute to disputes (Cui, 2014).

Disputes can be resolved through various mechanisms and it is not being true to say that all disputes are resolved by court proceedings or in other formal or informal settings involving Alternative Dispute Resolution methods (ADR) (Chong and Zin, 2012). Type of dispute resolution strategy can be identified by considering their efficiency in terms of time and money according to the nature and complexity of the dispute.

It can be identified that there are pros and cons to every dispute resolution method practiced and selection of an appropriate dispute resolution method is vital as every project is likely to have disagreements (Chong and Zin, 2012). Usually litigation involves a lengthy process, capacious documentation, procedural and adversarial in nature (Merna and Bower, 1997). Thereby ADR explored the context and cost and time saving have been realised (Chon and Zin, 2012). However, Danuri *et al*. (2012) mentioned that ADR would not be successful if the parties did not have mutual respect and understanding between the parties and ADR will not bring the desired outcome if either side did not have the genuine desire to resolve the dispute by a simple method. ADR will be inappropriate where one party does not want a settlement and it may also be in the commercial interests of a party to delay a hearing (Harmon, 2003). Obviously, if the disputing parties are not willing to settle, going through ADR process would just be a waste of time.

In this scenario, the importance of establishing an inventive problem solving approach which can address above stated shortcomings is highlighted.

2.3. TRIZ METHODOLOGY

TRIZ (a Russian abbreviation for the Theory of Solving Inventive Problems) was originated by the Russian Scientist and Engineer Genrich Altshuller (Sohn, 2013). As defined by Livotov (2008) "TRIZ is an inventive and technical problem solving tool which improves a single part or characteristic of the system without impairing other parts or characteristic of the system or adjacent systems". Altshuller proved that inventive problems can be tackled through a systematic approach (Souchkov, 2013). He started his work by studying thousands of patents, looking for commonalties, repetitive patterns and principles of inventive thought. After investigating approximately 400,000 patent descriptions, Altshuller found that newly discovered physical principles were used in only 0.3% of all patented solutions (Souchkov, 2013). In addition, it appeared that a great number of inventions complied with a relatively small number of basic solution patterns (Domb, 2015). The author further codified, documented and published his findings which attracted number of Scientists, Engineers, and inventors (Stratton *et al.,* 2000). Together the research continued, eventually resulting in the screening of more than two million patents and from which numerous analytical and knowledge based tools for solving inventive problems were developed.

According to Savransky (2000), following four specific features can be identified in TRIZ methodology; human oriented, knowledge based, systematic and inventive problem solving. The basic idea in TRIZ is that systems evolve in similar ways, and by reducing any situation and problem to a physical level, standard solutions and problem solving techniques extracted from different fields can be applied (Yan *et al.,* 2014). As Vignesh and Natarajan (2013) stated, the process of solving a problem using TRIZ includes, identification of the problem, comparing and matching the problem with the general TRIZ problems, finding the general TRIZ solution that is related to the problem and development of ideal solutions related to problem.

Based on above process, TRIZ can be approached under three main steps (Yan *et al*., 2014).

- The "formulation" phase - where the expert uses different tools to express the problem in the form of a contradiction network or another model.
- Abstract solution finding phase - where access to different knowledge bases is made to get one or more solution models. TRIZ users need to be capable of choosing the accurate abstract solution according to the current abstract problem.
- The "interpretation" phase - where these solution models are incorporated with the help of the scientific-engineering effects, knowledge base, to get one or more solutions to be implemented in the real world.

TRIZ methodology is mainly used in technical problem solving but it can be effectively used for non-technical problems (Savransky, 2000). Although it has shown effectiveness when applied to domestic industries, especially manufacturing, there are no cases of it being applied to the field of construction (Sohn, 2013).

2.4. REVIEW ON THE APPROPRIATENESS OF TRIZ BASED APPROACH FOR CONSTRUCTION DISPUTE RESOLUTION

Construction industry deals with complex nature which ultimately results in number of disputes due to different views of parties. Existing dispute resolution strategies generally aim at conventional problem solving methods as often complex contexts are extremely simplified, alternatives ignored, constraints avoided, risk not evaluated correctly and resources, knowledge and potentials not utilized for the best problem solving at the right time (Livotov, 2008). In this scenario, TRIZ provides a great advantage over other problem solving tools as it is a faster and more effective problem solving and innovation processing tool (Domb, 2015).

In contrast to the common “trial and error” problem solving methods such as brainstorming, morphological analysis etc. used in dispute resolution process, TRIZ only relies on the unbiased laws of evolution of technical systems and therefore enables a focused search for possible solutions (Livotov, 2008). The difficulty of existing dispute resolution strategies is that too much information has to be browsed and there is no guarantee of moving in a right direction. TRIZ organizes translation of the specific problem into abstract problem and then proposes to use a generic principle or a pattern, which is relevant to the type of the problem (Souchkov, 2013).

TRIZ evolutionary criteria such as adaptability, controllability and periodic occurrences complete the systematic approach to the problem which is highly applicable to construction industry (Livotov, 2008). Also it reduces the generic risk of missing an important solution to a specific problem as it provides a broad range of generic patterns of inventive solutions (Souchkov, 2013). It is a completely open approach that amplifies individual creativity, rather than limiting exploration to a narrow solution space in the way that traditional methods do. Furthermore, it is not necessary to be highly experienced in the use of TRIZ in order to generate creative results (Catháin and Mann, 2013). Therefore, from a new perspective, Cui (2014) proposed a TRIZ theory perspective on construction conflict resolution.

Through different TRIZ methodologies, there are “40 Inventive Principles” which has been successfully used in number of other fields rather than other methods as an innovative problem solving approach. Hence, “40 Inventive Principles” method was used in constructing TRIZ-DR model under this study. Each principle in the collection recommends a number of directions for solving a particular type of an inventive problem which is very much applicable in respect with construction dispute resolution. As 40 inventive principles were mainly developed regarding engineering applications, some principles were identified as non-related in resolving construction disputes due to their high technical nature. Through a desk study, 23 inventive principles were identified which can be applicable in construction dispute resolution as shown in Table 1. Therefore, the aforementioned findings were used in developing the study findings which are explained in next sections.

Table 1 : Interpretation of TRIZ Inventive Principles

TRIZ inventive principle	Meaning
1. Segmentation	Divide an object into independent parts
2. Extraction	Remove or separate a needless part from an object, or extract and utilize the necessary part
3.Local quality	Place each part of the object under conditions most favourable for its operation
4.Asymmetry	Replace a symmetrical form with an asymmetrical form of the object
5.Merging	Combine in space or in time homogeneous objects or objects destined for contiguous operations
6.Universality	Have the object perform multiple functions, eliminating the need for other objects
7.Nested doll	Placing one object inside another
8.Preliminary action	(Prior counter-action)
9.Beforehand cushioning	Compensate relatively low reliability of an object with countermeasures taken in advance
10.Equipotentially	Change the condition of the work so an object doesn’t need to be raised, lowered, rotated, etc.
11.Dynamics	Make characteristics of an object, or outside environment, adjusting for optimal performance or operation for different internal or external conditions
12.Another dimension	Remove problems by moving an object in a line by two-dimensional movement
13.Continuity of useful action	Carry out an action without breaks - all parts of an object should constantly operate at full capacity
14.Intermediary	Use an intermediary object to transfer or carry out an action

15.Self Service	Make an object serve itself by performing auxiliary helpful functions, Use waste resources, energy, or substances.
16.Copying	Use simple and inexpensive copy instead of an object, which is complex, expensive, fragile or inconvenient to operate
17.Cheap short living objects	Replace an expensive object by a collection of inexpensive ones
18.Porous materials	Make an object porous or use additional porous elements.
19.Color changes	Change the colour of an object or its surroundings; change the degree of transparency of an object or its surroundings, etc.
20.Homogeneity	Make objects interact with a primary object having the same properties or ones close to its behaviour
21.Discarding and Recovering	Regenerating materials and parts after they has completed its function or become useless.
22.Phase transition	Use effects, which are relieved during phase transition.
23.Composite materials	Replace a homogeneous material with a combination of materials

Source: (Cui, 2014)

3. RESEARCH METHODOLOGY

Research design is a logical blueprint which can be explicit or implicit (Yin, 2013). The design of this research includes, literature survey, expert opinion survey and data analysis. Background study and a comprehensive literature review were carried out in order to identify the different concepts practiced in TRIZ methodology and to identify the benefits of TRIZ over the other DR strategies. This research was then subjected to a mix method research approach using in-depth interviews with subject matter experts by considering the nature of the study. Thereby, semi structured interviews with seven subject matter experts were carried out in gathering details in determining the adaptation and application of TRIZ-DR model to construction dispute resolution. The interviews were conducted until the data saturation is reached, among the subject matter experts who belong to consultant, contractor and client organizations. Manual code based content analysis was used to analyse the qualitative data and statistical mode was used in analysing the quantitative data gathered in this study. The findings of data analysis were assisted in discovering the urge of TRIZ methodology in construction dispute resolution and developing the TRIZ-DR model ultimately.

4. RESEARCH FINDINGS AND DISCUSSION

4.1. COMMONLY USED DISPUTE RESOLUTION STRATEGIES AND THEIR DRAWBACKS

As the first step of this study, semi structured interviews were carried out with subject matter experts to identify existing dispute resolution strategies and their drawbacks. Gathered data were analysed using manual code based content analysis. Respondents categorised commonly used dispute resolution strategies into two methods; informal dispute resolution methods and formal dispute resolution methods. Under informal dispute resolution methods, they have stated that negotiations and mediations are mostly used by parties as first choice of dispute resolution process, whereas amicable settlement is least used. Adjudication is the most commonly used formal dispute resolution strategy and as the final step of dispute resolution, litigation is also practiced in resolving construction disputes when parties are not satisfied with ADR methods.

However, most of the dispute resolution strategies take considerable amount of time to come up with a solution such as litigation and arbitration generally undergo more than one year to reach a solution. High cost is also another major drawback of existing dispute resolution methods such as adjudication, arbitration and litigation. Sometimes, cost occurred for arbitration process can be more than 20% of contract sum of the project. Furthermore, lack of expertise knowledge may cause to unsuccessful outcomes in dispute resolution methods and lack of enforceability and legality of informal dispute resolution methods is another drawback as parties often tend to seek solution, which can be enforced by law. Hence, drawbacks of existing dispute resolution strategies can be summarised as lack of innovativeness, high cost and time involvement and limited knowledge, which urge the need of an innovative DR solution to eliminate the associated drawbacks.

4.2. *TRIZ-DR MODEL FOR CONSTRUCTION DISPUTE RESOLUTION*

During the next step of the study, the sixteen common construction disputes identified through literature review (refer Section 2.1) were assessed by the subject matter experts according to their impact and frequency of occurrence in a construction project using three point likert scale: High (3), Medium (2) and Low (1). The gathered data were analysed using the statistical mode. Accordingly, common construction disputes based on their occurrence are presented in Table 2. The highlighted construction disputes were eliminated as they have low impact and low occurrence, and hence 11 out of 17 disputes were considered as common construction disputes in the industry

Table 2: Impact and Occurrence Analysis of Construction Disputes

No.	Dispute	
1	Contractual disputes	High impact / High occurrence
2	Time Delays	
3	Delay in approvals	
4	Document errors	High impact / Medium occurrence
5	Delayed Payments	
6	Frequent and late changes to design	
7	Management related disputes	Medium impact / Medium occurrence
8	Material delivery delays	
9	Construction defects	
10	External factors (Market, Political, Weather)	
11	Quantity measurement and evaluation	
12	Contractor – Subcontractor relationship	Low impact / Low occurrence
13	Contractor Employer relationship	
14	Termination	
15	Lack of communication	
16	Contractor's poor financial control	
17	Employer interference	

Subsequently, twenty three TRIZ inventive principles identified during the literature survey were assessed by the subject matter experts according to their importance and level of applicability as per their experience. Three point likert scale, i.e. High (3), Medium (2) and Low (1), was used in data collection and statistical mode was calculated in data analysis. The research findings are summarised in Table 3.

Table 3: Importance and Applicability Analysis of TRIZ Tools

No.	TRIZ tool	
1	Segmentation	Highly important / Highly applicable
2	Extraction	
3	Nested doll	Highly important / Medium applicable
4	Intermediary	
5	Homogeneity	
6	Local quality	Medium importance / Medium applicable
7	Merging	
8	Universality	
9	Preliminary action	
10	Equipotentiality	
11	Dynamics	
12	Continuity of useful action	
13	Copying	
14	Composite materials	
15	Another dimension	Medium importance / Low applicable
16	Beforehand cushioning	
17	Discarding and recovering	
18	Phase transitions	Low important / Low applicable
19	Self-service	
20	Cheap short living objects	
21	Porous materials	
22	Asymmetry	
23	Color Changes	

Therefore, TRIZ tools with Medium importance / Low applicable and Low important / Low applicable were eliminated from the group as all respondents agreed their applicability in resolving construction disputes is negligible. Subsequently, the respondents were requested to assess the level of applicability of fourteen (14) TRIZ tools in resolving eleven (11) common construction disputes identified in Table 2. The findings are presented in TRIZ-DR Matrix in Figure 1. "H" signifies highly applicable TRIZ tools in resolving particular dispute whereas "M" and "L" denotes moderately applicable and least applicable TRIZ tools in resolving particular dispute respectively. The study finally developed TRIZ-DR model incorporating TRIZ-DR matrix as presented in Figure 1. The implementation process of the model is discussed below.

PHASE 1

The construction dispute should be identified and defined in this phase of TRIZ-DR model. The nature of the dispute should be clearly identified and contractual background should be examined prior to using TRIZ-DR matrix. Dispute identification leads to analyse technical conflict of the scenario. TRIZ-DR model mainly focuses on solving most common and frequently occurred construction disputes hence identification of dispute category of the selected dispute is essential in this phase.

PHASE 2

After identifying the nature and extent of the dispute, it should be analysed with TRIZ matrix to identify most appropriate TRIZ tools which can be used in solving specific dispute. After identifying the category of the specific dispute, it can be identified the TRIZ tools which are more applicable in resolving such dispute using TRIZ-DR matrix.

Example: If the dispute is about a global claim, as per the nature of the dispute it is fallen within the contractual dispute category. As per TRIZ-DR matrix, TRIZ tools of Segmentation, Extraction, Merging, Universality, Nested doll, Preliminary action and Continuity of useful action have the higher applicability in resolving this type of construction disputes. So those tools can be clearly identified as the most appropriate TRIZ tools to be applied in this scenario.

PHASE 3

This is the most important phase of the TRIZ approach where inventive solutions are derived to the specific dispute interpreting basic TRIZ solutions. Experience and overall knowledge about the dispute is vital in this phase for the practitioner to generate innovative solutions. The above example stated in Phase 2 can be analysed as following in this phase.

Example: After identification of the most appropriate TRIZ tools using TRIZ-DR matrix, interpretation for each and every basic solution should be done to come up with solution for the dispute. As per 1st TRIZ tool, Segmentation defines breaking and object into independent parts. This is the basic solution provided by TRIZ inventive principles. Interpretation of this basic solution to the specific dispute is generally based on the experience and skill of the practitioner. The interpretation of Segmentation tool to generate solution above dispute can be discussed as follows.

Segmentation tools generally define breaking an object into identifiable independent parts to simplify the process. When applying this basic solution to contractual dispute regarding global claim it can be identified that global claim is presented as mix of each and every event occurred within the construction project which may or may not be resulted in delaying the project. So identification of events which have had impact on delaying the project is crucial.

As suggested by Segmentation tool, breaking the global claim into identifiable independent parts simplifies the evaluation of global claim. For this scenario "cause and effect analysis" can be performed in order to identify delay events. The solution of breaking global claim into independent parts as cause and effect of each event is derived through the basic solution of TRIZ segmentation tool.

After interpreting and deriving a solution for the specific dispute through TRIZ approach, it should be assessed on technical grounds whether it can be practically applied to the scenario. In this phase it should be identified whether the solution is derived within contractual limitations of the project and if not whether parties are mutually agreed to implement the solution which is out of contractual grounds. Hence, the feasibility of the suggested solution is evaluated during this phase 3. If the solution is not feasible, the dispute should be assessed through TRIZ-DR matrix again to identify other appropriate solutions to the specific dispute.

PHASE 01

PROBLEM IDENTIFICATION

ABSTRACTING PROBLEM
Define the dispute
Define the scope

PHASE 02

ABSTRACT SOLUTION FINDING

TRIZ-DR MATRIX

DISPUTE \ TRIZ-TOOL	Segmentation	Extraction	Local Quality	Merging	Universality	Nested Doll	Preliminary Action	Equipotentiality	Dynamics	Continuity of useful action	Intermediary	Copying	Homogeneity	Composite Materials
Contractual Disputes	H	H	M	H	H	H	H	L	L	H	H	H	M	L
Time Delays	H	H	H	H	H	H	L	L	L	H	L	L	L	L
Delay in Approvals	H	H	H	H	H	L	H	H	L	H	H	H	M	L
Document Errors	H	H	H	H	H	L	H	H	H	H	H	L	M	H
Delayed Payments	H	H	L	H	L	L	H	H	M	H	L	M	L	L
Frequent and Late Changes to Design	H	M	M	M	L	H	L	M	M	H	M	M	L	M
Management related Disputes	H	M	M	H	L	M	H	M	L	L	M	L	H	H
Material Delivery Delays	H	H	L	H	H	L	H	M	M	H	H	H	L	L
Construction Defects	M	L	H	L	L	L	L	M	L	L	L	L	M	L
External Factors (Market, Political, Weather)	H	L	H	H	M	M	L	L	L	H	L	L	H	L
Quantity measurement and evaluation	M	M	M	H	M	H	M	L	L	M	M	H	L	L

NOT FEASIBLE

PHASE 03

SPECIFIC SOLUTION FINDING

INTERPRETATION OF SOLUTION
AND
EVALUATION OF THE FEASIBILITY OF SUGGESTED SOLUTION

FEASIBLE

PHASE 04

IMPLEMENTATION

IMPLEMENTATION OF THE FINAL SOLUTION

Figure 1: TRIZ-DR Model

PHASE 4

If the solution is deemed to be practical, it should be implemented with immediate effect to resolve the existing dispute.

5. CONCLUSIONS

Construction is a complex process that requires the coordinated effort of a temporarily assembled multiple-member organization of many discrete groups. As each group is having different goals and needs, and each expecting to maximise its own benefits, it is inevitable that disputes may arise. Many researches revealed that identifying the causes and early settlement of the dispute is crucial as if not solved in timely manner disputes may tend to drag on and cause project failures.

There are many dispute resolution strategies currently practiced in the construction industry. Applicability of each existing dispute resolution strategy is governed by the nature and extent of the dispute. The main drawbacks of existing dispute resolution strategies can be identified as high cost and time involvement, limited innovation and limited application of inventive solutions. There is a growing awareness in the construction industry to adapt an innovative dispute resolution strategy which can address above issues effectively. As a systematic inventive tool, TRIZ methodology can be used to generate innovative ideas through identifying root cause of the dispute. An overall process of TRIZ methodology enables to systematically define and solve any given dispute in an effective manner. As to addressing drawbacks of existing dispute resolution strategies, this research presents the novel TRIZ-DR model for construction dispute resolution. .

This novel TRIZ-DR model is applicable in resolving any construction dispute despite the nature and background of the dispute. The model is bound around four main phases such as problem identification, abstract solution finding, specific solution finding and implementation. Further it shows the synergy between TRIZ inventive principles and common construction disputes through generated TRIZ-DR matrix. In transforming the TRIZ-DR model to practitioners' language, the step by step procedure; abstracting problem, relating to TRIZ-DR matrix, interpretation, suggesting a solution, checking the feasibility of the solution and implementation to be followed at each phase is also specifically incorporated within the model itself. Hence, the novel model facilitates a systematic dispute resolution procedure for effective dispute resolution in construction industry.

6. REFERENCES

Assaf, S., Khalil, M., and Hamzi, M. 1995. Causes of delay in large building construction projects. *Journal of Management in Engineering*, 11(2), 45-50.

Cabrera, R., and Li, G. 2014. A lean-TRIZ approach for improving the perfomance of construction projects. *In: conference proceedings IGLC-22 Norway,* June 2014. 883-894. Oslo: Norway.

Catháin, C., and Mann, D. 2013. Construction innovation using TRIZ. 296-306. Available from http://www.irbnet.de/daten/iconda/CIB15607.pdf [Accessed 20 June 2015].

Cheung, S.O., and Suen, H. C. H. 2002. A multi-attribute utility model for dispute resolution strategy selection. *Construction Management and Economics*, 20(7), 557-568.

Cheung, S., Tam, C., and Harris, F. 2000. Project dispute resolution satisfaction Classification through neural network. *Journal of Management in Engineering,* 16(1), 70-79.

Cheung, S. and Yeung, Y. 1998. The effectiveness of the Dispute Resolution Advisor system: a critical appraisal. *International Journal of Project Management,* 16(6), 367-374.

Chong, H., and Zin, R. 2012. Selection of dispute resolution methods: factor analysis Approach. *Engineering, Construction and Architectural Management,* 19(4), 428 – 443

Cui, H. (2014). Exploring Conflict Resolution Methods for Construction Projects: A TRIZ Theory Perspective. In: *ICCREM 2014*, China 27-28 September 2014. USA: ASCE press, 791-796.

Danuri, M.S.M., Ishan, Z.M., Mustaffa, N.E. and Jaafar, M.S., 2012. A revisit on the current practice of dispute resolution and ADR in the Malaysian construction industry. *Journal of Design and Built Environment*, 10(1), 1-13

De Alwis, I., Abeynayake, M. and Francis, M. 2016. Dispute avoidance model for Sri Lankan construction industry. In: *5th World Construction Symposium 2016: Greening Environment, Eco Innovations and Entrepreneurship*, July 2016. University of Moratuwa: Sri Lanka, 162-173.

Domb, E. 2015. Find the Zones of Conflict – Identify the Problem. *The TRIZ Journal*. Available from http://www.triz-journal.com/innovation-methods/innovation-triz-theory-inventive-problemsolving/find-zones-conflict-identify-problem/ [15th August 2015]

Fenn, P., Lowe, D., and Speck, C. 1997. Conflict and dispute in construction. *Construction Management and Economics*, 15(6), 513-518.

Harmon, K. M. J. 2003. Resolution of construction disputes: A review of current methodologies. *Leadership and management in engineering*, 3(4), 187-202.

Kumaraswamy, M.M.1997. Conflicts, claims and disputes in construction. *Engineering, Construction and Architectural Management*, 4(2), 95 – 111.

Livotov, P. 2008. *TRIZ and Innovation Management*. Innovator. 08/2008 ISSN 1866-4180. European TRIZ Association ETRIA

Merna, A., and Bower, D. 1997. *Dispute Resolution in Construction and Infrastructure Projects.* 1st ed. Hong Kong: Asia Law and Practice Publishing Ltd.

Savransky, S. D. 2000. *Introduction to TRIZ Methodology of Inventive Problem Solving*. Florida: CRC Press LLC.

Stratton, R., and Mann, D. 2003. Systematic innovation and the underlying principles behind TRIZ and TOC. *Journal of Materials Processing Technology*, 139(2003), 120–126.

Stratton, R., Mann, D. and Otterson, P., 2000. The Theory of Inventive Problem Solving (TRIZ) and Systematic Innovation-a Missing Link in Engineering Education? *TRIZ Journal*. [online] Available from http://www.researchgate.net/publication/228901791_The_theory_of_inventive_problem_solving(TRIZ)and_systematic_innovationa_missing_link_in_engineering_education [Accessed 25 September 2015]

Sohn, M. S. 2013. *Application of TRIZ for creative phase in design-VE. SAVE*. [online] Available from http://www.value-eng.org/knowledge_bank/attachments/200443.pdf [Accessed 12 August 2015]

Souchkov, V. 2013. Accelerate Innovation with TRIZ. *TRIZ Journal.* [online] Available from http://www.xtriz.com/publications/AccelerateInnovationWithTRIZ.pdf [Accessed 25 August 2015]

Vignesh, K., and Natarajan, U. 2013. Introduction to TRIZ concept. In: *National Conference on Emerging Trends in Mechanical Engineering 2013,* India 09 November. India, 203-207.

Wall, C. (1998). The dispute resolution adviser in the construction industry, in *Construction Conflict Management and Resolution*, Fenn, P., and Gameson, R. (eds). London, 25-27 September 1998. London: Spon, 328-339.

Yan, W., Merk, C., Cavallucci, D., and Collet, P. 2014. An ontology-based approach for inventive problem solving. *Engineering Applications of Artificial Intelligence*, 27(1), 175-190.

USE OF ENERGY RETROFITS TO REDUCE THE ENERGY DEMAND OF EXISTING OFFICE BUILDINGS

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ABSTRACT

Continuous increase of energy demand is a common issue faced by people around the globe. Meanwhile, buildings have been identified as one of the major contributors for the ever-rising energy demand of the world. Consequently, buildings nowadays are built while giving more attention to the ways of reducing building energy demand. However, the existing buildings which are expected to occupy the majority of the total building stock for many years to come, are still being operated with a higher energy demand. Accordingly, building energy retrofits are identified as an efficient approach to reduce the energy demand of the existing buildings, and the aim of this research is to study the use of energy retrofits in office buildings of Sri Lanka.

The research approach was predominantly quantitative, which was followed by three case studies. A thorough literature survey was carried out to identify the prevalent retrofit techniques and the practicable enablers to enhance the use of energy retrofits. Findings of the literature survey was validated by a pilot survey before carrying out the questionnaire survey. Subsequently, three case studies were conducted to determine the costs and benefits of implemented retrofit techniques.

The results of the study showed that the use of energy retrofits in Sri Lankan office buildings sector is at a lower level. Further, the case study results depicted that the selected retrofit projects have generated significant energy savings which had led to better project feasibility. It was also established that the use of energy retrofits could be enhanced by implementing the identified enablers based on the perception of the building managers.

Keywords: *Energy Demand; Energy Retrofits; Office Buildings.*

1. INTRODUCTION

The world is currently facing an intense energy crisis due to the unavailability of energy sources to cope with the rising energy demand which is increasing at a rate of 1.6% on average annually (Öztürk *et al.*, 2013). According to Diakaki *et al.* (2008) building sector uses large amounts of energy and it is among the greater energy consumers in the world. Furthermore, office buildings have been identified as one of the highest energy consumers among the whole built environment (Gamage and Lau, 2015).

Various building designs and construction techniques have been evolved lately to improve the energy efficiency of the new buildings; however, the proportion of new buildings constructed every year is relatively smaller compared to existing building stock (Reed and Wilkinson, 2005). Consequently, constructing energy efficient buildings in the future would not reduce the present energy demand as the existing buildings have a significant effect on the total energy demand for many years to come (Asadi *et al.*, 2012). Hence, a rapid improvement of energy efficiency in the existing buildings is essential to reduce the global energy demand (Ma *et al.*, 2012).

Cost effective building energy retrofits are identified as one of the best methods of reducing the energy demand of the existing buildings (Huang *et al.*, 2012). Further, according to Mathew *et al.* (2005) improving the energy

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performance of existing buildings would yield an annual median savings of 16%. However, the selection of the most relevant retrofit is a challenging task due to the availability of numerous retrofitting options and their impacts on the building energy demand (Nik *et al.*, 2016). Hence this research was conducted with the aim of studying the use of building energy retrofits for the existing office buildings in Sri Lanka to reduce the energy demand. In order to achieve this aim, the current use of energy retrofits and the enablers to enhance the use of energy retrofits were identified. Further, the financial viability of the implemented retrofit projects was established through case studies.

Initially different categorisations of energy retrofit were identified, out of which demand side, conventional retrofits were chosen as the most effective and financially viable retrofit option in reducing building energy demand. Then a thorough literature review was conducted to identify available demand side energy retrofit techniques and the enablers to enhance the use of energy retrofits. Based on the literature findings, the level use of energy retrofits and the perception of building managers towards the identified enablers were established through the questionnaire survey. Finally, three case studies were conducted to establish the financial viability of implemented retrofit techniques.

2. TYPES OF ENERGY RETROFITS

Energy retrofitting is an area with a broad scope which covers energy efficiency measures from a minor alteration to a major refurbishment project, and hence there is a wide variety of energy retrofits used for buildings (Chunduri, 2014). Classifying energy retrofits based on the energy conservation method and the amount of energy saved are the two most popular classifying methods (Ma *et al.*, 2012).

Table 1: Types of Retrofits Based on Energy Conservation Method

Retrofit type	Energy conservation method
Supply side management	Generation of renewable energy
Demand side management	Reduction of building energy demand
Human factors management	Change of energy consumption patterns

Table 1 indicates the classification of energy retrofits based on the energy conservation method used. Here, the supply side management retrofits include renewable technologies like solar photovoltaics, biomass, wind energy and geothermal power systems (Pisello *et al.*, 2016). According to Ma *et al.* (2012) supply side retrofits provide alternative electrical and thermal energy to buildings. On the other hand, retrofit technologies for demand side management aims at implementing energy efficient equipment and low energy technologies to reduce overall energy demand of the building (Kromer, 2007). Moreover, Ma *et al.* (2012) have identified that energy savings could be achieved by optimising comfort requirements, occupancy regimes, occupant activities and access controls through proper human factors management.

The energy savings that could be achieved by changing occupant behaviour is comparatively less and are temporary in nature as the human behaviour could change rapidly. Whereas the savings from demand side and supply side management retrofits are bound to be high and tend to last for longer durations. However, according to Zhang *et al.* (1993) proper demand side management could altogether avoid the need for new sources of energy or in other words supply side retrofits. Further, the demand side retrofits require comparatively less cost investments compared to retrofit measures using renewable energy technologies (Kromer, 2007).

Table 2: Types of Retrofits Based on the Amount of Energy Saved

Retrofit type	Amount of energy saved
Existing Building Commissioning (EBC)	Up to 15%
Standard retrofit	15-45%
Deep retrofit	45% and above

Table 2 indicates the other most prominent retrofit classification, where the retrofits are classified based on the amount of energy saved. Wang *et al.* (2013) have defined EBC as a process which incorporates identification and implementation of energy saving opportunities of the existing equipment and operations to make the buildings work properly. Consequently, the energy saving opportunities of buildings could be maximised by improving building operation process and altering maintenance procedures (Trubiano *et al.,* 2014). On the other hand, conventional retrofits generally focus on upgrading individual systems to achieve the potential energy savings of each building system (Penna *et al.,* 2015). However, deep retrofits adapt a whole-building approach by addressing multiple building systems simultaneously (Moser *et al.,* 2012). Authors have further described deep energy retrofits as a combination of many EBC and conventional retrofits

EBC provides comparatively lower energy savings, although it is the easiest type of retrofit to be implemented. Moreover, according to Krieske and Hu (2014) despite the higher energy savings from deep retrofits, the risk involved is also significant due to the complexity and high cost of the implementation process. Consequently Ma *et al.* (2012) have described conventional retrofits as the most cost effective and low risk retrofit type for existing buildings in general.

According to the above clarifications it could be stated that the use of conventional retrofits for demand side management are expected to result in adequate energy savings at an optimum cost and risk to the building managers and owners. Hence this study is narrowed down to conventional energy retrofits to manage the energy demand of the buildings.

3. RESEARCH METHODOLOGY

The aim of this research was to study the use of energy retrofits in office buildings of Sri Lanka. Initially a literature survey was conducted to determine the available energy retrofit techniques and the enablers to enhance energy retrofit use. Subsequently, data collection was carried out in three phases.

3.1. PHASE 1 - PILOT SURVEY

The pilot survey was conducted to validate the findings of literature survey. Here the applicability of literature findings to the Sri Lankan building context was examined. Accordingly, for the pilot survey, a senior Facility Manager with industry experience of more than 20 years was interviewed.

3.2. PHASE 2 - QUESTIONNAIRE SURVEY

The questionnaire survey was conducted to identify the level of use of energy retrofits in office buildings of Sri Lanka and to establish the importance of enablers to enhance energy retrofit usage. For this purpose, office buildings in Colombo area, with more than 7 storeys which were built on or before 2010 were considered as the population of the study. Buildings having more than 7 storeys were considered as the identified energy retrofit techniques are highly effective in larger buildings. On the other hand, buildings built on or before 2010 were taken as the retrofit requirement arises only in older buildings. The combination of above two requirements revealed an adequate building population from which a sample of 41 buildings were selected randomly for questionnaire survey. Lists of buildings were taken from the records of Colombo Municipal Council and major construction contractors for random sample selection. The questionnaires were distributed to the building managers of the selected buildings. Out of the 41 distributed questionnaires only 35 were returned with a satisfactory response.

3.3. PHASE 3 - CASE STUDIES

The main focus of the case studies was to carry out a cost benefit analysis of the implemented retrofit techniques. For this purpose, three specimen case studies were conducted. The three cases were selected in a way to represent the most commonly used retrofit technique in each of the three categories; building facade, heating ventilation and air conditioning (HVAC) system and lighting system as identified in the questionnaire survey. For each retrofit technique, recently concluded largest retrofit project in terms of the project cost was selected. These projects were identified during the questionnaire survey. Further, the computed energy savings in the case studies were converted to monetary terms based on the tariff rates defined by the Public Utilities Commission of Sri Lanka.

4. Energy Retrofit Techniques for Buildings

Building facade and systems installed for HVAC and lighting are considered as the main energy aspects of a building (Dascalaki and Santamouris, 2002). Hence the building energy retrofits could be adapted to reduce energy demand of a building by addressing these three main energy aspects.

During the literature survey, 19 building energy retrofit techniques belonging to the above three energy aspects were identified. Out of the identified 19 techniques, 2 techniques were invalidated during the pilot survey defining them as either preventive or corrective maintenance techniques but not as retrofit techniques. These two retrofit techniques were high albedo roof painting and the renovation of the window frame. The validated retrofit techniques and the level of use of these retrofit techniques in the established building sample is depicted in Table 3. Here the use of these techniques was identified in two aspects as to whether the techniques were available from the beginning (inherent) or whether the techniques were retrofitted later. Because, in some of the modern buildings these techniques were installed during the initial building commissioning. Hence it is identified separately from actual retrofit scenarios.

Table 3: Usage of Energy Retrofit Techniques

Technique	% of buildings where the techniques were inherent	% of buildings where the techniques were retrofitted	Total usage (%)
Roof Retrofits			
Roof Insulation	22.86	8.57	31.43
Green Roof Application	0	0	0
High-albedo Roof Paintings	-	-	-
Wall Retrofits			
Wall Insulation	14.29	5.71	20.00
Solar Shading Elements	11.43	20.00	31.43
Window Retrofits			
Low Emissivity Application	11.43	22.86	34.29
Multi Panel Glazing	5.71	14.29	20.00
Vacuum Tube Window	0	0	0
Renovation of Window Frame	-	-	-
HVAC Retrofits			
Optimum Start/Stop Controller	11.43	11.43	22.86
Variable Frequency Drives (VFD) for Motors	17.14	34.29	51.43
Free Cooling Applications	11.43	17.14	28.57
Energy Recovery Ventilator (ERV)	8.57	14.29	22.86
Demand Control Ventilation (DCV)	11.43	20.00	31.43
Lighting Retrofits			
Light Emitting Diode (LED) Lighting	5.71	28.57	34.29
Task Lighting	0	8.57	8.57
Occupancy Based Lighting Control System	0	0	0
Daylight Linked Lighting Control System	2.86	0	2.86
Lighting Controlled by Time Scheduling	5.71	14.29	20.00

5. Enablers to Promote the Implementation of Energy Retrofits

During the literature survey, 8 enablers were identified in two levels as organisational level and national level. Further, 2 organisational level enablers and one national level enabler were added based on the findings of the pilot survey. However, the implementation of the enablers is solely dependent upon the attitude of the building managers of the organisation. Hence, the attitude of Sri Lankan building managers towards the importance of each of the organisational and national level enablers should be properly identified before enacting and empowering these enablers in to practice. Because, there is little use in implementing these enablers, if the building managers refuse to embrace these enablers in enhancing the energy retrofit usage to minimise the energy demand of the building facilities. However, it is not possible to implement all the enablers at once. Hence the established enablers of the two categories were prioritised based on the RII computed from the responses which is depicted in Table 5. For the prioritisation, a five-point importance level scale was used.

Table 5: Prioritisation of Enablers

Enabler	RII
Organisational level enablers	
Allocating higher budgets for energy improvements	0.908
Leniency on expected payback from retrofit projects	0.874
Energy performance measurement and verification protocol	0.846
Identifying and hiring competent contractors	0.806
Raising awareness of the building managers on energy retrofit techniques	0.754
National level enablers	
Energy Service Contracts (ESCOs)	0.938
Financial incentives from the government for energy improvements	0.914
Energy performance certification system for buildings	0.834
Financial assistance from banks to improve energy efficiency	0.822
Tax relief for energy efficiency related imports	0.766
Regulations on energy performance of existing buildings	0.726

The results clearly indicated that out of the organisational level enablers, the building managers have given the highest importance for the allocation of higher budgets for energy improvements which indicated a RII of 0.908. According to Mathews *et al.,* (2010) opportunities for building managers to carry out energy improvements are restricted by the limited funding allocations. Hence the increase in funding for energy improvements would provide the necessary freedom for the building managers to implements the relevant energy improvements. Further, the leniency on expected payback of energy improvement projects received a RII of 0.874 indicating that the building managers are conscious about the long-term benefits of energy improvements over higher payback periods. Moreover, the existence of an energy performance measurement and verification protocol and identifying and hiring competent contractors have both received RII values over 0.8 (0.846 and 0.806 respectively) which indicates a high importance. However, raising awareness of the building managers received the lowest importance with a RII of 0.754.

Further, the results clearly indicated that, out of the established national level enablers, the highest importance was given to ESCOs with a RII of 0.938. As indicated in literature, Vine (2005) has stated that in an ESCO arrangement, the initial capital cost of a retrofit implementation borne and the process of project implementation is looked after by the energy service company. Hence, it is not essential for the client to tie up significant amount of capital at the start of the project. Furthermore, according to (Sorrell, 2007) the ESCOs are PAYS arrangements, where risk of under realisation of estimated savings is also transferred to the contractor, which would attract the building managers even more. Financial incentives from the government was ranked second in the list of national level enablers with a RII of 0.914. According to Menassa (2011), even the repayable incentives from the government usually involves very low interest rates which are almost negligible for a profitable energy retrofit project. However, the risk of failure lies with the building managers and the owners and hence would demand a higher certainty of the savings of each retrofit technique to be implemented.

Moreover, when the priority order of the enablers is observed, it is noticeable that the enablers which result in financial assistance have gained a higher RII. However, the building energy performance certification system has gained a slightly higher a RII (0.834) compared to financial assistance from banks which has received a RII of 0.822. According to Wang *et al.* (2012), obtaining a building performance certification from an accredited organisation or the government would result in more positive implications on the public image of the organisation. Conversely, tax relief for energy efficiency related imports received a comparatively lower RII (0.766) as it is helpful only when a building manager takes the responsibility of implementing an energy retrofit improvement in-house which is not that frequent. However, building regulations on energy demand of buildings was placed at the bottom end of the prioritised national level enablers as it gained a RII of 0.726. Pan and Garmston (2012) have stated that the building regulations force the building managers to enhance the energy performance of existing buildings by incorporating retrofit techniques, which could moreover result in fines and compensations if the minimum requirements are not attained. Hence the building regulations are more of a hostile approach in facilitating building retrofit implementation, which have received a lower importance level from the respondents.

6. COST BENEFIT ANALYSIS OF THE RETROFIT TECHNIQUES

It was evident from the analysis of questionnaire data that the use of energy retrofit techniques of the existing office buildings of Sri Lanka is not at a satisfactory level. Albeit this lower retrofit usage, still there are facilities which have successfully implemented retrofit projects. Following case studies have discussed the costs and benefits of the implemented retrofit techniques. Costs and benefits were analysed by using two project appraisal techniques which are simple payback period (SPP) and net present value (NPV). Here, the two techniques analyse two different attributes of the retrofit projects. SPP indicates the speed of recovering the initial capital cost while NPV depicts the life time profit of the project by considering the time value of money. The monetary savings achieved due to the reduction of energy demand, as a result of the implemented retrofit techniques were used as the cash inflows of the projects.

As mentioned in section 2, case studies were used for an in-depth study of the most commonly used retrofit technique of each of the three categories; building facade, HVAC and lighting systems. According to the outcomes of the questionnaire survey, the most utilised retrofit technique in each of the three categories were as follows.

- HVAC system- Variable frequency drivers (VFD) for motors (51.43%)
- Lighting system- LED lighting (34.29%)
- Building Facade- Solar control low emissivity application (34.29%)

6.1. CASE STUDY 1- VFD RETROFIT PROJECT

Chilled water of the HVAC system of the selected facility was pumped and transferred throughout the building using four 55 kW pumps. Initially the pumps have been installed to match full load capacity, accounting for the general public who visit the premises for various purposes. However, as the occupancy level of premises varies frequently, the cooling system was found to be working at a part load on majority of the duration. Hence 55kW VFDs were retrofitted to all four chilled water pumps to save energy by operating pumps below the maximum capacity during part load conditions. Costs, benefits and the project feasibility values are depicted in Table 6.

Table 6: Cost Benefit Analysis of VFD Retrofit Project

Project Cost (LKR)	Average Annual kWh Savings (LKR)	Average Annual kVA Savings (LKR)	SPP of the project (years)	NPV of the project (LKR)
4,800,000	7,094,800.8	1,240,080	0.58	53,744,202.74

In addition to the energy savings, the VFD retrofit project has result in several additional benefits as well. After the VFD retrofit implementation, the occupant comfort level has been identified to be improved. Moreover, a better control of the pump operations has been achieved through the project with the enhanced opportunity of carrying out a more in-depth analysis of the pump faults. Further, the VFD has been highly helpful in planning preventive maintenance of different elements of the chilled water pumps. Consequently, the better preventive maintenance of the elements of the pumps is expected to pro long the useful life time of the pumps.

6.2. CASE STUDY 2- LED LIGHTING RETROFIT PROJECT

Existing inefficient lamps of the common areas of the selected facility were replaced by LED lamps. Subsequently, previously existed Tube-in-Tube, sodium vapour, halogen, fluorescent lamps of the common areas of the building were replaced with more efficient LED units. However, the expected maximum demand saving value was minute compared to the overall maximum demand of the building and hence not taken to appraise the project. Computed costs, benefits and the project feasibility values are included in Table 7.

Table 7: Cost Benefit Analysis of LED Retrofit Project

Project Cost (LKR)	Average Annual kWh Savings (LKR)	Average Annual kVA Savings (LKR)	Simple payback period of the project (years)	Net present value of the project (LKR)
4,480,398.25	2,605,202.04	-	1.72	18,302,093.59

The LED retrofit project has resulted in an elevation of the illuminance level in the common areas. The reason for this illuminance enhancement has been explained as the uni-directional nature of the LED lamps. Further a minor reduction of heat load has also been expected as the heat emission of LEDs are lower compared to all the other traditional lamps that existed in the facility. As a rule of thumb in the industry, 1 kWh of air conditioning energy is saved for every 3 kWh of lighting energy saved. Moreover, extended life span of the LED lamps is another additional benefit. The expected life span of an LED lamp is 14 years and it is significantly higher than the other traditional lamps. Hence, a replacement cost is also saved for the organisation, due to the reduced frequency of replacements.

6.3. CASE STUDY 3- LOW EMISSIVITY COATING RETROFIT PROJECT

Main factor that has motivated the incorporation of low emissivity coating was the east-west orientation of the building. This orientation embraces a higher solar thermal load in to the building which in turn increases the cooling load for the air conditioning system. All the windows of the east and west faces of the building facade were applied with law emissivity coatings. However, similar to LED retrofit project, the expected maximum demand saving value was minute compared to the overall maximum demand of the building and hence not taken to appraise the project. Costs of the project, benefits due to realised energy savings and the resulting project feasibility values are depicted in Table 8.

Table 8: Cost Benefit Analysis of Low Emission Retrofit Project

Project Cost (LKR)	Average Annual kWh Savings (LKR)	Average Annual kVA Savings (LKR)	Simple payback period of the project (years)	Net present value of the project (LKR)
184,860	385,946.28	-	0.48	1,397,519.75

Low emissivity retrofit project has helped in minimising the penetration of UV rays, which would protect the internal equipment like furniture from fading. Further, the reflectance of UV rays also creates a better indoor environment quality which is suitable for the occupants. However, the reflectance of solar heat would not impact the illuminance level as the visible rays are allowed to pass through the low emissivity coating. Moreover, the shatter resistance of glass is also expected to be enhanced by the addition of low emissivity coating.

7. DISCUSSION

The results of the case studies clearly indicate that the financial viability of the implemented retrofit projects is at a highly satisfactory level. All three retrofit projects had SPP of less than 2 years, which indicate that the initial cost investment is recovered in very quick time. Moreover, the life time savings of all 3 retrofits projects were massive which is indicated from the NPV of each project. In addition to the direct monetary savings, all three retrofit projects were expected to generate additional benefits which could result in indirect monetary savings. The success of these real retrofit scenarios would be good examples for energy conscious building managers.

8. CONCLUSIONS

The energy demand for buildings are continuously rising with the increasing occupant expectations. In order to manage the increased user requirements, the modern buildings are constructed with sophisticated technologies aimed at reducing building energy demand. However, the portion of energy demanded by the existing older buildings are significant. Hence, improving the energy efficiency of existing buildings to bring down the energy demand is really important in solving the current global energy crisis. Energy retrofitting is one of the key approaches of reducing the energy demands of the existing buildings.

The aim of this study was to study the use of energy retrofits in the existing office buildings of Sri Lanka to reduce the building energy demand. During the data collection, it was revealed that the use of energy retrofits in Sri Lankan office buildings are at a lower level. The most commonly used retrofit technique was VFDs which had a total usage of only 51.43%. The level of use of all the other retrofit techniques were way below 50%. However, the use of energy retrofits could be enhanced by the implementation of enablers, both at the organisational level and the national level. According to the perception of the building managers the most preferred enabler strategy was to implement ESCOs which had a RII value 0.938. Moreover, the profitability of energy retrofit projects as demonstrated through the three case studies were acceptable, due to the reduction of energy demand of each respective building facility by significant amounts. All three cases had SPP of less than 2 years for the respective retrofit projects which shows the viability of those projects. Hence, by implementing energy retrofits with aid of the established enablers, the energy demand of Sri Lankan office buildings could be reduced. Thus, the findings of the research could be benefit for energy mangers or facility mangers towards taking decisions on energy management.

9. REFERENCES

Asadi, E., Da Silva, M. G., Antunes, C. H., and Dias, L. 2012. Multi-objective optimization for building retrofit strategies: A model and an application. *Energy and Buildings*, 44, 81-87.

Chunduri, S. 2014. *Development of planning and design phases of an integrative building life-cycle process model for advanced energy retrofit projects* (Unpublished doctoral dissertation). The Pennsylvania State University.

Dascalaki, E., and Santamouris, M. 2002. On the potential of retrofitting scenarios for offices. *Building and Environment*, 37(6), 557-567.

Diakaki, C., Grigoroudis, E., and Kolokotsa, D. 2008. Towards a multi-objective optimization approach for improving energy efficiency in buildings. *Energy and Buildings*, 40(9), 1747-1754.

Gamage, W., and Lau, S. S. 2015. Perception of indoor environment quality in differently ventilated workplaces in tropical monsoon climates. *Procedia Engineering*, 118, 81-87.

Huang, Y., Niu, J., and Chung, T. 2012. Energy and carbon emission payback analysis for energy-efficient retrofitting in buildings—Overhang shading option. *Energy and Buildings*, 44, 94-103.

Krieske, M., and Hu, H. 2014. The scalability of the building retrofit market: A review study. In: *IEEE Conference on Technologies for Sustainability*, 24-26 July 2014. Oregon.

Kromer, S. 2007. Efficiency Valuation: How to “Plan, Play and Settle” Energy Efficiency Projects. *Strategic Planning for Energy and the Environment*, 27(1), 69-78.

Ma, Z., Cooper, P., Daly, D., and Ledo, L. 2012. Existing building retrofits: Methodology and state-of-the-art. *Energy and Buildings*, 55, 889-902.

Mathew, P., Kromer, J., Sezgen, O., and Meyers, S. 2005. Actuarial pricing of energy efficiency projects: lessons foul and fair. *Energy Policy*, 33(10), 1319-1328.

Mathews, J. A., Kidney, S., Mallon, K., and Hughes, M. 2010. Mobilizing private finance to drive an energy industrial revolution. *Energy Policy*, 38(7), 3263-3265.

Menassa, C. C. 2011. Evaluating sustainable retrofits in existing buildings under uncertainty. *Energy and Buildings*, 43(12), 3576-3583.

Moser, D., Liu, G., Wang, W., and Zhang, J. 2012. Achieving deep energy savings in existing buildings through integrated design. *ASHRAE Transactions*, 118(2).

Nik, V. M., Mata, E., Kalagasidis, A. S., and Scartezzini, J. 2016. Effective and robust energy retrofitting measures for future climatic conditions—Reduced heating demand of Swedish households. *Energy and Buildings*, 121, 176-187.

Öztürk S., Sözdemir A., and Ülger O. 2013. The real crisis waiting for the world: Oil problem and energy security. *International Journal of Energy Economics and Policy*, 3, 74-79.

Pan, W., and Garmston, H. 2012. Compliance with building energy regulations for new-build dwellings. *Energy*, 48(1), 11-22.

Penna, P., Prada, A., Cappelletti, F., and Gasparella, A. 2015. Multi-objectives optimization of Energy Efficiency Measures in existing buildings. *Energy and Buildings*, 95, 57-69.

Pisello, A. L., Petrozzi, A., Castaldo, V. L., and Cotana, F. 2016. On an innovative integrated technique for energy refurbishment of historical buildings: Thermal-energy, economic and environmental analysis of a case study. *Applied Energy*, 162, 1313-1322.

Reed, R. G., and Wilkinson, S. J. 2005. The increasing importance of sustainability for building ownership. *Journal of Corporate Real Estate*, 7(4), 339-350.

Sorrell, S. 2007. The economics of energy service contracts. *Energy Policy*, 35(1), 507-521.

Trubiano, F., Brennan, M., and Albee, K. 2014. Advanced energy retrofit – designing integrated design roadmaps. In *3rd International High Performance Buildings Conference*, July 14-17, 2014. Purdue.

Vine, E. 2005. An international survey of the energy service company (ESCO) industry. *Energy Policy*, 33(5), 691-704.

Wang, S., Yan, C., and Xiao, F. 2012. Quantitative energy performance assessment methods for existing buildings. *Energy and Buildings*, 55, 873-888.

Wang, L., Greenberg, S., Fiegel, J., Rubalcava, A., Earni, S., Pang, X., and Hernandez-Maldonado, J. 2013. Monitoring-based HVAC commissioning of an existing office building for energy efficiency. *Applied Energy*, 102, 1382-1390.

Zhang, X., Romannelli, M., Hssaine, C., and Zhang, K. M. 1993. *Demand side management*. Executive summary. Draft: October 15, 2015 [online]. Available from: http://www.tompkinscountyny.gov/files2/planning/energyclimate/documents/Demand%20Side%20Management%2010-15-15.pdf [Accessed 15 April 2016].

WHAT DOES DEVELOPING LEAN CAPACITY MEAN?

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ABSTRACT

There has been an increase in lean implementation in the construction industry during last few decades, but the progress has been hampered by several barriers. This is due to evidence that suggest the misconceptions regarding lean and its applicability to the construction industry. It appears that either the industry does not recognize lean as a capacity enhancing measure to contribute to bottom line success, and /or there is an inability to overcome the barriers that prevent the uptake of lean. Although, construction literature related to lean implementation barriers and solutions are available in the worldwide, there is a lack of research in capacities that excel lean. Hence, there are two major issues that need to be addressed. Firstly, an insightful discourse on what is meant by lean (as a means of capacity enhancing) is required. Secondly, type of capacities needed to overcome some of the barriers already identified in literature, is necessary. In developing this paper, the strong inter-connectedness of both issues is recognized. In this regard, this paper will discuss the contextual aspects in relation to developing lean capacities necessary to overcome the barriers and to successful lean implementation in the construction industry. A literature review was carried out to discuss the unique characteristics of lean construction and reasons for lean implementation failure to identify the context of lean capacity. The findings revealed that, lack of capacities as the prevalent issue for construction companies to enable lean and these capacities need to be evidently defined for the successful lean implementation. Having considered the construction literature, lean capacity can be defined as the hard/soft resources of an organization which enable maximizing value and minimizing waste of a competitive organization. Lean capacities can divide into 2 categories as soft resources (attitude, capability, knowledge, experience, skill to direct or lead the change and improvements, strategic leadership, program and processes management and networking creation) and hard resources (dedicated employees' time, allocation of fund, means of communication, information, material, financial resources, machineries, technologies/ methodologies, facilities and infrastructure) of an organization. These capacities will allow lean implemented construction organisations to be retained and exceled in lean. Hence, construction organizations need to establish lean capacities to maximize the lean performance and thereby increase competitiveness.

Keywords: *Capacity; Lean Capacity; Lean Construction; Resources.*

1. INTRODUCTION

Construction industry in many parts of the world suffers from problems such as workmanship defects, time, and cost overrun to name few (Harrington, Voehl & Wiggin, 2012). As globalization proceeds, developing countries and their enterprises face major challenges in strengthening their human and institutional capacities to take advantage of trade and investment opportunities (OECD, 2004). Lean has various inherent direct advantages that enhance the organizations ability to successfully compete through being more effective and efficient in their operations (Hu, Mason, Williams & Found, 2015). In addition to these more obvious benefits, there are some notable indirect advantages that arise from successful lean implementation (Hu et al., 2015).

Thus, this paper begins with an introduction to lean implementation in the construction industry. The next section present lean construction concept to elaborate the benefits and barriers of lean implementation for construction organizations. Misconceptions about lean and its applicability to the construction industry will discuss in detail to analyse the barriers for lean implementation. Section 3 discusses capacities to overcome the barriers in lean implementation followed with a special emphasis to define lean as a means of capacity enhancing in the next section. Finally, importance of lean capacity present together with a contextual model to enable lean in the construction industry.

2. LEAN IMPLEMENTATION AND ADOPTION IN THE CONSTRUCTION INDUSTRY

Lean strategy brings a set of proven tools and techniques to reduce lead times, inventories, set up time, equipment downtime, scrap, rework and other wastes of the hidden factory (Kumar, Antony, Singh, Tiwari & Perry, 2006). Principles of lean thinking have been broadly accepted by many production/operation managers and applied successfully across many disciplines (Bhamu & Sangwan, 2014). One main tenet of lean thinking is that everything can be further improved (Andersen, Belay & Seim, 2012). There is an increasingly positive trend in the construction industry to implement lean and seek the required improvement targets (Nesensohn, Bryde, Ochieng, Fearon & Hackett, 2014). Having the characteristics of both production and service systems, the construction industry also taken some steps toward applying the lean production concept (Howell, 1999). Moreover, lean construction seeks to adopt lean production methods into construction (CRC for Construction Innovation, 2007).

Koskela, Howell, Ballard and Tommelein (2014) introduced two slightly differing interpretations of lean construction. One interpretation about the application of lean production concepts to construction and the other interpretation views lean production as a theoretical inspiration for the formulation of a new, theory-based method for construction, called lean construction (Koskela *et al.*, 2014). However, Aziz and Hafez (2013) specified that lean construction is using the same principles as lean production to reduce waste and increase the productivity and effectiveness in construction work. Lean construction is a way forward to design production systems to minimise waste of materials, time and effort which leads to possible generation of maximum amount of value (Marhani, Jaapar & Bari, 2012). Organizations have been adopting lean concept which is a process improvement and problem solving approach for achieving higher degree of quality (Prasanna & Vinodh, 2013).

2.1. BARRIERS FOR LEAN IMPLEMENTATION

Mossman (2009) specified that number of circumstances influence against successful lean implementation and none of them on their own are able to evade. Accordingly, there seems to be some barriers to the successful implementation of lean construction (Ogunbiyi, Oladapo & Goulding, 2013). A survey conducted by the practitioners of lean implementation revealed that changes to the production environment due to lean have only a 30% success rate and 70% of lean implementations experience decay and return to the original way of doing business (Schipper & Swets, 2010). Moreover, only 32% of the surveyed companies in Abu-Dhabi were found to be familiar with and using lean techniques and the majority emphasized the need for a practical framework for adopting lean techniques (Aomar, 2012). This indicates that lean implementation is not free from barriers (Jadhav, Mantha & Rane, 2014).

Shang and Pheng (2014) identified people and partner, managerial and organizational hurdles, lack of support and commitment, cultural and philosophical issues, government related issues and procurement related issues as barriers for lean practices in the Chinese construction industry. Further, Shang and Pheng (2014) specified that the lack of a long-term philosophy and the absence of lean culture in their organizations are the most crucial obstacles to lean practice in the construction industry. The factors that hinder companies from implementing lean are ineffective inventory management, lack of supplier participation, lack of quality improvements and quality control and lack of employee participation and top management commitment (Rahman, Sharif & Esa, 2013). Key reported obstacles of adopting lean techniques in Abu-Dhabi specified by Aomar (2012) include the financial crisis in the economy. Hence, construction managers consider lean initiative as an added cost and hence no lean initiation can grasp in construction projects. Therefore, lack of top/senior management involvement (commitment and support) identified as another barrier. However, many authors (Rahman *et al*., 2013; Jadhav *et al*., 2014; Shang and Pheng, 2014; Green, Harty, Elmualim, Larsen & Kao; 2008; Aomar, 2012; Smart Market Report, 2013) agreed to workers' resistance to change as the major barrier for lean implementation. According to the authors, workers oppose to change from their regular routine of work and adapt to new technology. Moreover, workers are not easy to educate and refuse to change due to lack of capacities. Therefore, these barriers hinder construction firms adopting lean construction.

2.2. MISCONCEPTIONS ABOUT LEAN AND ITS APPLICABILITY TO THE CONSTRUCTION INDUSTRY

Lean has both positive views (Howell & Ballard, 1999; Hines, Holweg & Rich, 2004; Bhamu & Sangwan, 2014) as well as contradicting views (Green, 1999). Green (1999) specified that most of the literature take it for granted that lean production is a ‘good thing’ and offer a coherent and seemingly persuasive argument in favour of transporting the principles of lean production into the construction industry in dark side of lean construction. Howell and Ballard (1999) answered by stating that Green misses the key foundations of lean which came from a long history of production management thinking and first attempts to manage the physics of production in the service of higher performance. Moreover, an important gap in the literature concerned with the lack of understanding of the relationships between the risks in lean implementation (Marodin & Saurin, 2015). According to Jadhav *et al*. (2014), lean implementation issues may vary from country to country, work culture of the organization and geographic location within the country. Rework, uncertainty, labour skills, site conditions and location are some examples of such factors that need further analyses for leaner construction processes (Al-Sudairi, 2007). Even though, construction industry appears to be one of the pioneering industries to absorb lean concepts and techniques (Shang & Pheng, 2014), lean do not receive the attention they deserve in the construction industry. The significance of lean implementation barriers according to lean practitioners and non-lean practitioners showed in Figure 1 as per the findings of McGraw hill construction in Smart Market report-2013.

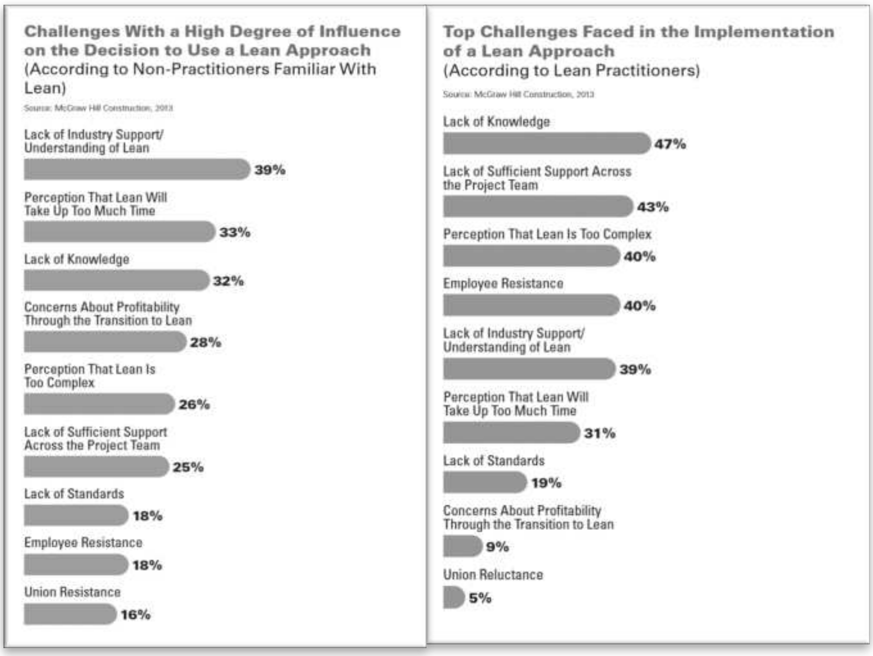

Figure 1: Significance of Lean Implementation Barriers According to Lean Practitioners and Non-Lean Practitioners

(Source: Smart Market report, 2013)

According to above Figure, lack of sufficient knowledge identified as the biggest barrier by lean practitioners. According to non-lean practitioners, the highest percentage (39%) found that lack of industry support and understanding of lean is a highly important challenge and 32% found that lack of knowledge is problematic. These findings demonstrated that the need of more information and education on lean to the industry. Those who have not implemented lean do not fully understand the challenges posed by working with project team members who are not engaged in lean. This also reinforces the call for necessary capacities to enable lean, so that firms understand the full benefit and major obstacles they face in implementing and retaining lean practices and can make informed decisions. It is necessary that companies rethink their business strategies and implement focused strategies (Guzman, Gutierrez, Cortes & Ramire, 2012) to overcome these barriers for construction industry to reap the benefits of lean construction implementation (Ogunbiyi *et al*., 2013). Similar to other researchers, Rymaszewska (2014) contended that organizations benefited from converting to lean, provided the process is adjusted by analysing the existing and required capacities.

3. CAPACITIES TO OVERCOME THE BARRIERS IN LEAN IMPLEMENTATION

Hines *et al*. (2004) specified that lean exists at two levels, the strategic and operational levels. The strategic level has the customer-centered thinking and involves everyone at the company, where the operational level does not. This has created a misunderstanding for the use of lean and many companies have their major focus on lean implementation on the shop floor level, without considering lean thinking. In order to implement the right tools and strategies to create customer value, it is crucial to understand lean and organizational capacities (Linné & Ekhall, 2012). Hence, the transformation towards lean construction will lead to changes in the culture and in its people (Green *et al*., 2008) where identification of existing capacities and required capacities are paramount for successful lean implementation.

Merinoa and Carmenado (2012) defined capacity as the existence of resources, networks, leadership and group process skills and capacity building is a cyclical concept related to the development of human, organizational, institutional and social capital. Capacity enforced with development projects through capacity building to have a more robust structure and to adaptive to changes (UNESCO, 2010). Hence, capacity building understood not only as human resource development but also as organizational and institutional development (UNESCO, 2010). Horton *et al*. (2008) define two categories of capacity that organizations need to develop: resources (staff, infrastructure, technology and financial resources) and management (strategic leadership, program and processes management and networking creation). Each of these categories has operational and adaptive aspects that have to established and maintained (Horton *et al*., 2008 cited in Merino & Carmenado, 2012).

Groot and Molen (2000) identified knowledge, skills and attitudes in individuals and groups of people relevant in design, development, management and maintenance of institutional and operational infrastructures and processes that are locally meaningful as some of the capacities of an organization. Similarly, Enemark and Ahene (2002) identified human resources in terms of knowledge, skills, personal and group attitudes for developing and managing certain areas in the community or an organization, which ensure long-term sustainability as organizational capacities.

Lean is not just a set of tools and techniques, but at its heart are the people (Ohno, 1988 cited in Bhasin, 2012). It is the people whose knowledge, intelligence and desire to improve that steers organizations to new levels of continuous improvement (Hines *et al*, 2008; Bhasin, 2012). Therefore, lean relies heavily on the skills of the people and how they respond to change (Sawhney & Chason, 2005) which is one of the major barrier for lean implementation for construction organizations. Hence, applying lean construction for design and construction within the industry is becoming a highly pertinent issue (Nesensohn *et al*., 2014). According to Koskela *et al*. (2014), lean-based construction requires changes in individual behaviour as well as the resources of the organization. This has clearly indicated the call for defined capacities for successful lean implementation. Hence, identification of capacities to overcome barriers of lean implementation will added an extra value for construction companies to better perform in the industry. Therefore, construction companies need to identify necessary capacities to obtain the full benefit of lean implementation.

4. WHAT IS MEANT BY LEAN AS A MEANS OF CAPACITY ENHANCING?

Lean interpreted in many ways by practitioners and academics that mean there is no real consensus around what lean specifically stands for and exact characteristics associated with the lean concept (Bhamu and Sangwan, 2014). Today many companies committed to lean. Hence, it is important to assess what lean principles these companies believe in and reflect upon how they affect the organization (Linné and Ekhall, 2012). If companies want to implement lean principles in their processes, they need to have a clearly stated lean philosophy. The philosophy is working as the basis for all other lean principles. It is essential to have one clear stated philosophy to benefit from the other lean principles. This philosophy should be shared throughout the entire organization to achieve outstanding results.

The origins of lean thinking found on the shop-floors of Japanese manufacturers and, in particular, innovations at Toyota Motor (Hines *et al*., 2004). Toyota developed the techniques that support the principles of lean production. However, Howell (1999) specified that this initiated by Taiichi Ohno at Toyota Motor Corporation. Lean is a management philosophy derived mostly from the Toyota Production System (TPS) and identified as lean only in the 1990s (Liker & Morgan, 2006). The term was coined by the research team working on international auto production to reflect both the waste reduction nature of the Toyota production system and to contrast it with craft and mass forms of production (Womack *et al*. 1991). The first applications of lean recorded in the Michigan plants of Ford in 1913, and then developed to mastery in Japan (within the TPS) (Laureani & Antony, 2012). Hines *et al*. (2004) stated that the techniques of eliminating waste and excess from the product flows were first introduced to automotive engine manufacturing, then to the automobile assembling, and later applied to the entire Toyota supply chain. During 1970s, supplier manuals produced and the secrets of this lean approach shared with companies outside Toyota for the first time (Hines *et al*., 2004). Many companies throughout the world are seeking to learn from Toyota's system. Typically they limit their exploration to a few superficial lean tools. Hence, organizations that have seen success with lean tools in manufacturing plants want to apply them to their own product development processes (Liker & Morgan, 2006) to maximise value while minimising the waste.

Waste is everything that does not directly contributes to add value to a product, under the perspective of customers' needs and requirements (Alves, Carvalho & Sousa, 2012). Womack and Jones (2003) describe waste (muda) as any human activity which absorbs resources, but creates no value. Thus, by eliminating waste, activities can become lean; which provides more with less resources (Womack & Jones, 2003). It includes all inefficiencies in a system as well as causes of these inefficiencies and called as muda (Womack & Jones, 1996). This is a fundamental concept of lean manufacturing and one of the most efficient ways of enhancing capacities and improving profitability of a company. However, the starting point of continuous improvement is to identify waste. There are seven types of waste identified under lean as overproduction, overstocking, excessive motion, waiting time, delay and transportation, extra-processing, defect and rework (Ogunbiyi *et al*., 2013). However, Alves *et al*. (2012) referred to non-utilization of human potential as the eighth waste where Green (1999) critique human stress also needs to add. Researchers found that many development activities treated as waste since they add no value to the final product (Liker & Morgan, 2006; Ward, 2007). The goal of lean philosophy is to design and manufacture products of high quality and low-cost in an efficient way through eliminating all waste (Hopp & Spearman, 2008). Henceforth, an organization needs focusing on eliminate waste to improve existing capacities and hence value addition.

At the heart of lean philosophy, value defined based on the customers' perspectives in terms of cost, product functions (Chen & Taylor, 2009). The importance of customer value is displayed by two levels of lean approach as strategic and operational. The strategic level of lean thinking requires understanding the value of customers where the operational level achieves requirements set by customers through the practice of lean production techniques (Hines *et al*., 2004). With a focus on enhancing value and reducing waste from a system's perspective, it argued that the lean philosophy and its basic elements address both design and production processes (Jørgensen & Emmitt, 2009).

However, researchers have given different meanings to lean (Alves, Milberg & Walsh, 2012; Alves, Azambuja & Arnous, 2016). Moreover, lean is highly interpretive and there is no shared definition or understanding of what is meant by lean, lean production, and lean construction (Jørgensen & Emmitt 2008). One of the reasons for the lack of a precise and widely accepted definition for what lean system entails is the lack of definition of lean production where it all started (Alves *et al*., 2012b). Despite the ever-growing literature on the topic, Lillrank (1995) highlights that the Japanese have not been very articulate about the reasons for their success. There was no great master plan up front and no blueprints that could have been studied. Therefore, the Japanese experience was widely open for various explanations and interpretations (Alves *et al*., 2012b). A closer look upon lean, history revealed fundamental differences between manufacturing and service environment. Arfmann and Barbe (2014) argued that the answers Toyota found for their problems through the development of lean do not provide an answer to many of the challenges faced by service organizations. The principles do not necessary work because service is different in push and pull practice, in the inability of storing capacity, in the creation process and especially in the variety of demand (Arfmann & Barbe, 2014). Koskela (2004) suggested that the principles presented by Womack and Jones (2003) are highly compressed and that they may harmful to the understanding of lean production as a whole, as many elements may missing in the explanation of the five lean thinking principles (Alves *et al*., 2012b). Womack and Jones (1996) codify that, the essence of lean production into five well-known basic principles as specify value, identify the value stream, avoid interruptions in value flow, let customers pull value, start pursuing perfection again. Koskela (2004) specified that the five principles provide an exhaustive, mature foundation equal to a theory for the transformation of any productive activity. Nevertheless, Howell (1999) specified that, the basic outline of lean production include

- Identify and deliver value to the customer value: eliminate anything that does not add value.
- Organize production as a continuous flow.

- Perfect the product and create reliable flow through stopping the line, pulling inventory, and distributing information and decision-making.
- Pursue perfection: deliver on order a product meeting customer requirements with nothing in inventory.

The key to success of implemented lean principles in processes is rather how people use the principles than the process itself (Liker & Meier, 2006). Many companies believe in lean as an approach to improve processes and thereby gain competitive advantage. However, it is unclear if lean is an approach to mitigate problems in an organization (Linné & Ekhall, 2012). Nevertheless, Laureani and Antony (2012) defined lean as a process improvement methodology used to deliver products and services better, faster, and at a lower cost. Hence, lean will enhance the existing capacities of an organization. In contrast, lean implementation required particular other capacities as well. It should be viewed in a wider context to achieve the overall goals (Enemark, 2003) as it differs from project to project and even organization to organization (Wal & Marks, 2007). However, Womack and Jones (2003) come closest to a definition as lean production is lean because it uses less of everything compared with mass production; half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. According to Howell (1999), lean is about building reliability. Alves *et al.* (2012b) commended that lean production evidenced as a model where the persons assume a role of thinkers and their involvement promotes the continuous improvement and gives companies the ability they need to face the market demands and environment changes. Moreover, it referred to as an integrated manufacturing system for minimising inventory levels and maximising capacity use through the minimisation of variability in the system (Wacker, 2004; de Treville & Antonakis, 2006; Fuentes & Dias, 2012).

Managing organizations under lean is different from typical contemporary practice as it has a clear set of objectives for the delivery process, for maximising performance for the customer at the project level, designs concurrently product and process and applies production control throughout the life of the project (Howell, 1999). Hence, lean enabling organizations are easy to manage and they are highly competitive in the industry. Unfortunately, neither resource nor capacities to enable lean in organizations have been explored. Hence, these resources need to evidently define for the successful lean implementation.

According to Jadhav *et al.* (2014), resources are primarily concerned about the human resources (soft resources) such as attitude, capability, knowledge, experience and skill to direct or lead the change and improvements. Physical (hard) resources include dedicated employees' time, allocation of fund, means of communication, information, material, machineries, technologies/methodologies, facilities and infrastructure (Jadhav *et al.*, 2014). Hence, lean capacity defined as the hard/soft resource of an organization which enable maximising value and minimising waste of a competitive organization. Hence, necessary lean capacities need to identify to optimize the benefits of lean implementation.

5. IMPORTANCE OF LEAN CAPACITY

Continuous improvements are important for companies to stay competitive in a changing environment. This is one of the benefits that companies believe in as a result of implementing lean in their organizations (Linné & Ekhall, 2012). Lean will allow companies to face continuous changes and disturbances, by giving them agility, the ability to quickly react to technical or environmental unpredictable problems or difficulties, to cope with such environments, companies need proactive workforces, and able, ready and motivated to think and suggest improvements (Alves *et al.*, 2012a). Hence, specific capacities need to carefully identify to overcome the barriers of lean implementation and hence, the identification of lean capacities. It is thus interesting to investigate on lean capacities. There exists a gap in current literature of how lean principles applied using company's existing capacities. Moreover, companies want to use their existing capacity as much as possible to get return on their investments (Christopher, 2005). The required lean capacity compared with the available capacity to identify capacity imbalances. Avoiding capacity imbalances are important since production resources available for adding value are associated with costs, regardless if the resources are used or not (Linné & Ekhall, 2012). On one hand, if the available capacity exceeds the requirements, this will lead to overcapacity and thereby low resource utilization. On the other hand, if a manufacturer lacks capacity it cannot meet the demand from customers and thereby experience loss of income. Nevertheless, majority of local construction organizations in developing countries lack capacity and cannot meet the demand of construction work (Enshassi, Al-Hallaq & Mohamed, 2006; Didibhuku & Mvubu, 2008 as cited in Kululanga, 2012). At the same time, high global competition demands construction organizations a higher level of capacity to maintain or increase steadily the performance of the business (Lagace & Bourgault, 2003). To sustain a fair level of competitiveness in both the domestic and global markets, they must strive to utilize lean capacities to reach the right markets in cost-effective ways (Singh, Garg & Deshmukh, 2010). Hence, identification of lean capacities will guide organizations to minimise the barriers of lean implementation and to optimise performance in the industry. Figure 2 shows a contextual model developed to overview how lean capacities pave the way towards lean enabling construction organizations.

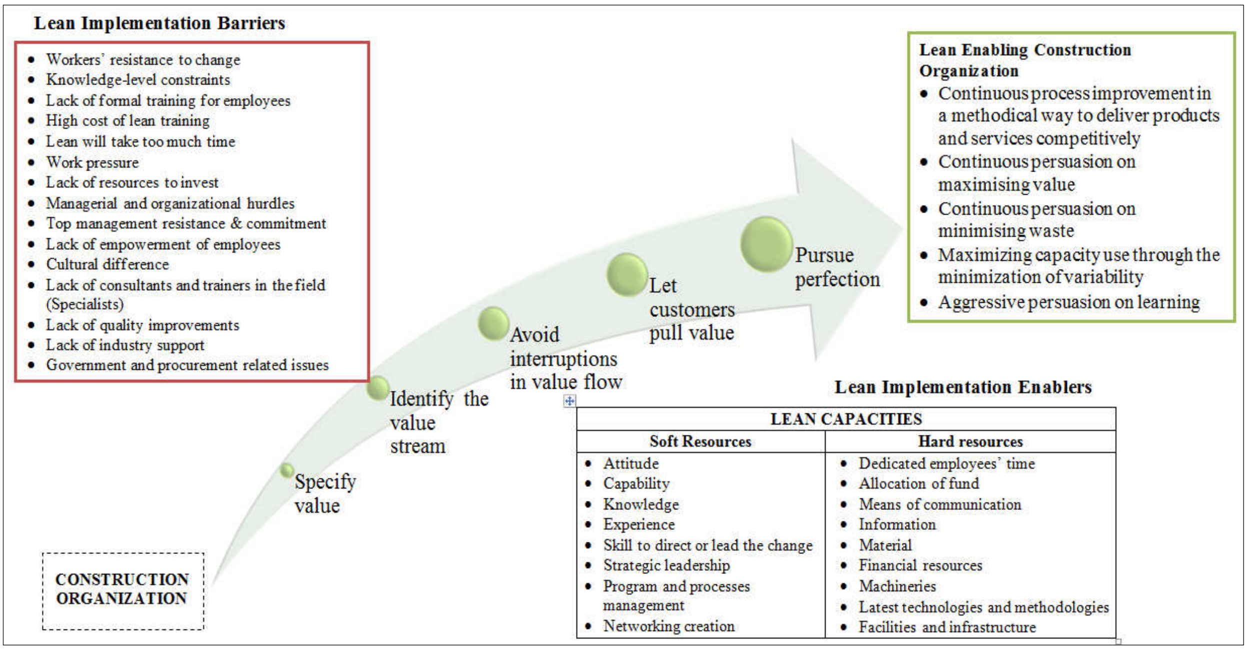

Figure 2: Contextual Model for Lean Enabling Capacities

According to Figure 2, construction organizations can overcome most of the challenges by lean implementation. By implementing five lean principles as shown in the middle arrow, pave the construction organization to lean enabling construction organization. Some of the distinct characteristics of lean enabling construction organization are present in the right top corner square. The lean enabling construction organization rich with characteristics such as continuous process improvement in a methodical way to deliver products and services competitively, continuous persuasion on maximising value and minimising waste, maximising capacity use through the minimisation of variability and aggressive persuasion on learning. These characteristics of lean enabling construction organization shows in the top right corner square of the contextual model. However, a successful lean implementation path is likely to be influenced by several factors which show in the left top corner square. Identified barriers are workers' resistance to change, knowledge-level constraints, lack of formal training for employees, high cost of lean training, lean will take too much time, work pressure, lack of resources to invest, managerial and organizational hurdles, top management resistance & commitment, lack of empowerment of employees, cultural differences, lack of consultants and trainers in the field (specialists), lack of quality improvements and quality control, lack of industry support and understanding of lean and government related issues and procurement related issues. Hence, construction organizations need rethinking of their business strategies and implement focused strategies, adjust process by analysing the existing and required capacities, understand lean and organizational capacities and changes in individual behaviour and the resources of the organization. These strategies will overcome lean implementation barriers and accelerate the process towards lean enabling organization. However, construction organizations lack capacities and are incapable of implementing such strategies. Therefore, it is important to investigate lean capacities which show in the bottom Table of the model. These lean capacities divided in to two categories as soft and hard resources of an organization. Soft resources include attitude, capability, knowledge, experience, skill to direct or lead the change and improvements, strategic leadership, program and processes management and networking creation. Hard resources include dedicated employees' time, allocation of fund, means of communication, information, material, financial resources, machineries, technologies/methodologies, facilities and infrastructure. However, this model identified only the contextual aspects of lean capacities and these aspects needs further investigation to ascertain the relationship to lean capacities. Further, this model describes a process which lean capacities developed.

6. CONCLUSIONS

There has been a notable growth in lean implementation in the construction industry. To integrate lean in a construction organization, it is recommended to understand and anticipate situations (barriers) that might be opposed to a proper implementation, as well as taking hold of those that can help ensure its success based on similar experiences in other contexts (Cano, Delgado, Botero, & Rubiano, 2015). Hence, this paper critically reviewed the current state of construction organization to identify the challenges faced by them and how lean implementation can solve the challenges. Many researchers highlighted the importance of implementing lean concepts and building capacities in the construction industry to obtain the full benefit of lean construction. Hence, it is essential to identify capacities necessary to overcome the barriers of lean implementation in the construction industry and hence, a clear understanding of the meaning of lean capacity. Therefore, this research paper defined what does lean capacity mean for the construction industry. Accordingly, lean capacity defined as the hard/soft resource of an organization which enable maximising value and minimising waste of a competitive organization. Lean capacities can divide in to two categories as soft resources (attitude, capability, knowledge, experience, skill to direct or lead the change and improvements, strategic leadership, program and processes management and networking creation) and hard resources (dedicated employees' time, allocation of fund, means of communication, information, material, financial resources, machineries, technologies/methodologies, facilities and infrastructure) of an organization. Even though most of the lean implementation barriers eliminated by lean capacities, certain barriers are within the control of the organization where one characteristic of lean capacity is the ability to identify the barriers relevant to their organization as these barriers are wary from organization to organization. However, some barriers are beyond the control of an organization which needs further analysis. The contextual model will guide the construction organization to overview the way towards successful lean implementation and describe the process for which lean capacities need to develop. Prior to the lean implementation, knowing this wide-set of barriers, it is advisable to provide a way to prevent their occurrence or mitigate their impact, based on acquaintance of the lean capacities to strengthen the lean implementation in the construction industry. As better lean practices achieved through identification of lean capacities, construction organizations need to focus on how to improve lean capacities in order to be competitive in the construction industry. Even though, lean and capacity related literature is discretely available in the worldwide, there is a lack of research in lean enabling capacities that enable lean in construction organizations. Hence, a proper empirical study required to recognize the lean capacities that excel lean. This paper based on literature review to define lean capacity. The definition will guide further researches. Drivers, benefits and barriers for lean capacities need further researches. Our future research will target to develop a lean capacity model with strategic guidelines to foster construction organizations.

7. REFERENCES

Al-Sudairi, A.A. 2007.Evaluating the effect of construction process characteristics to the applicability of lean principles. *Construction Innovation*, 7(1), 99-121.

Alves, A.C., Carvalho, J.D., and Sousa, R.M. 2012a. Lean production as promoter of thinkers to achieve companies' agility. *The Learning Organization*, 19(3), 219-237.

Alves, T.C.L., Milberg, C. and Walsh, K.D. 2012b. Exploring lean construction practice, research, and education. *Engineering, Construction and Architectural Management*, 19(5), 512 – 525.

Andersen, B., Belay, A. M., and Seim, E. A. 2012. Lean construction practices and its effects: a case study at St Olav's integrated hospital, Norway. *Lean Construction Journal*, 122-149.

Aomar, R. 2012. Analysis of lean construction practices at Abu Dhabi construction industry. *Lean Construction Journal*, 105-121.

Arfmann, D. and Barbe, F.T. 2014. The value of lean in the service sector: a critique of theory and practice. *International Journal of Business and Social Sciences*, 5(2), 18-24.

Aziz, R.F. and Hafez, S.M. 2013. Applying lean thinking in construction and performance improvement. *Alexandria Engineering Journal*, 52(2013), 679–695.

Bhamu, J. and Sangwan, K.S. 2014. Lean manufacturing: literature review and research issues. *International Journal of Operations and Production Management*, 34(7), 876–940.

Bhasin, S. 2012. An appropriate change strategy for lean success. *Management Decision*, 50(3), 439-458.

Cano, S., Delgado, J., Botero, L., and Rubiano, O., 2015. Barriers and success factors in Lean Construction's implementation - Survey in pilot context. In: Proc. *23rd Ann. Conf. of the Int'l. Group for Lean Construction*. Perth, Australia, July 29-31, 631-641.

Chen, H. and Taylor, R. 2009. Exploring the impact of lean management on innovation capability. In *PICMET 2009 Proceedings,* August 2-6, Portland, Oregon, 826-834.

Christopher, M. 2005. *Logistics and supply chain management; creating value - adding networks.* Harlow, England: Prentice Hall.

CRC for Construction Innovation (2007*). Final report: offsite manufacture in Australia Final report off-site manufacture in Australia*. Brisbane: CRC for Construction Innovation.

De Treville, S. and Antonakis, J. 2006. Could lean production job design be intrinsically motivating? contextual, configurational, and levels-of-analysis issues. *Journal of Operations Management*, 24(2), 99-123.

Enemark, S. and Ahene, R. 2002. Capacity building in land management– implementing land policy reforms in Malawi. *FIG XXII International Congress,*Washington, D.C. USA.

Enshassi, A., Al-Hallaq, K. and Mohamed, S. 2006. Causes of contractor's business failure in developing countries: the case of Palestine. *Journal of Construction in Developing Countries*, 11(2).

Fuentes, J.M. and Díaz, M.S. 2012. Learning on lean: a review of thinking and research. *International Journal of Operations and Production Management*, 32(5), 551–582.

Green, S. D., Harty, C., Elmualim, A. A., Larsen, G. D. and Kao, C. C. 2008.On the discourse of construction competitiveness. *Building Research and Information*, 36(5), 426-435.

Green, S.D. 1999. The dark side of lean construction: exploitation and ideology. In proceedings *IGLC 07*.University of California, Berkeley, CA, USA.21-32.

Groot, R. and van der Molen, P., Eds. (2001). *Workshop on capacity building in land administration for developing countries.* Final report on workshop held at ITC, Enchede.

Guzman, G.M., Gutierrez, J.S., Cortes, J.G. and Ramirez, R.G. 2012.Measuring the competitiveness level in furniture SMEs of Spain. *International Journal of Economics and Management Sciences*, 1(11), 09-19.

Harrington, H.J., Voehl, F. and Wiggin, H. 2012.Applying TQM to the construction industry. *The TQM Journal*, 24(4), 352-362.

Hines, P., Holweg, M. and Rich, A. 2004.Learning to evolve. *International Journal of Operations and Production Managemen*t, 24(10), 994-1011.

Hopp, W. J. and Spearman, M. L. 2008. *Factory Physics*. 3rd ed. Long Grove, Illinois: Waveland Press.

Howell, G.A. 1999. What is lean construction-1999. In *IGLC 7* held on 26-28 July 1999, University of California, Berkeley, CA, USA.

Howell, G.A. and Ballard, G. 1999. Bringing light to the dark side of lean construction: a response to Stuart Green. In *IGLC 07*. 26-28 July 1999, University of California, Berkeley, CA, USA.

Hu, Q., Mason, R., Williams, S.J. and Found, P. 2015. Lean implementation within SMEs: a literature review. *Journal of Manufacturing Technology Management*, 26 (7), 980-1012.

Jadhav, J.R., Mantha, S.S. and Rane, B. 2014.Exploring barriers in lean implementation. *International Journal of Lean Six Sigma*, 5(2), 122-148.

Jørgensen, B. and Emmitt, S. 2009. Investigating the integration of design and construction from a "lean" perspective. *Construction Innovation*, 9(2), 225–240.

Koskela, L.J., Howell, G.A., Ballard, G. and Tommelein, I. 2014. *The foundations of lean Construction.* [Online] 211-226. Available from: http://www.researchgate.net/publication/28578914 [Accessed 21 July 2016]

Kululanga, G. 2012. Capacity building of construction industries in Sub-Saharan developing countries: A case for Malawi. *Engineering, Construction and Architectural Management.* 19(1), 86-100.

Kumar, M., Antony, J., Singh, R. K., Tiwari, M. K. and Perry, D. 2006.Implementing the lean sigma framework in an Indian SME: a case study. *Production Planning and Control*, 17(4), 407-423.

Lagace, D. and Bourgault, M. 2003. Linking manufacturing improvement programs to the competitive priorities of Canadian SMEs. *Technovation*, 23(8), 705-715.

Laureani, A. and Antony, J. 2012. Critical success factors for the effective implementation of Lean Sigma. *International Journal of Lean Six Sigma,* 3(4), 274-283.

Liker, J.K. and Morgan, J.M. 2006. The Toyota way in Services: The case of lean product development. *Academy of Management Perspectives,* 05-20.

Lillrank, P. 1995. The transfer of management innovations from Japan. *Organization Studies*, 16(6), 971–989.

Linné, A. and Ekhall, C.J. 2013. L*ean capacity planning: planning for maximising customer value*. Gothenburg, Sweden: Repro service, Chalmers.

Marhani, M.A., Jaapar, A. and Bari, N.A.A. 2012. Lean construction: towards enhancing sustainable construction in Malaysia. *Social and Behavioral Sciences,* 68(2012), 87–98.

Marodin, G.A. and Saurin, T.A. 2015. Classification and relationships between risks that affect lean production implementation: A study in southern Brazil. *Journal of Manufacturing Technology Management,* 26(1), 57–79.

Merino, S. S., and Carmenado, I.D.L.R. 2012.Capacity building in development projects. Social and Behavioral Sciences, 46, 960-967.

Mossman, A. 2009. There really is another way, if only he could stop for a moment and think of it; Why isn't the UK construction industry going lean with gusto?. *Lean Construction Journal,* 24-36.

Nesensohn, C., Bryde, D., Ochieng, E., Fearon, D. and Hackett, V. 2014.Assessing lean construction maturity.In Proceeding of the IGLC-22, June 2014 | Oslo, Norway, 1157–1168.

OECD, 2004. Promoting entrepreneurship and innovative SMEs in a global economy: towards a more responsible and inclusive globalization. *2nd OECD conference of ministers responsible for small and medium-sized enterprises (SMEs)*. Istanbul, Turkey 3-5 June 2004.

Ogunbiyi, O.E., Oladapo, A.A. and Goulding, J.S. 2013.A review of lean concept and its application to sustainable construction in the UK. *International Journal of Sustainable Construction Engineering and Technology*, 4(2), 82-92.

Prasanna, M. and Vinodh, S. 2013.Lean six sigma in SMEs: an exploration through literature review. *Journal of Engineering, Design and Technology,* 11(3), 224-250.

Rahman, Sharif and Esa, 2013. Lean manufacturing case study with Kanban system implementation. *Economics and Finance*, 7(2013), 174–180.

Rymaszewska, A.D. 2014. The challenges of lean manufacturing implementation in SMEs. *Benchmarking: An International Journal,* 21(6), 987-1002.

Sawhney, R. and Chason, S. 2005. Human behaviour based exploratory model for successful implementation of lean enterprise in industry. *Performance Improvement Quarterly,* 18(2), 76-96.

Schipper, T. and Swets, M. 2010. *Innovative lean development: how to create, implement and maintain a learning culture using fast learning cycles.* New York: Productivity Press.

Shang, G. and Pheng, L.S. 2014. Barriers to lean implementation in the construction industry in China. *Journal of Technology Management in China*, 9(2), 155–173.

Singh, R.K., Garg, S.K. and Deshmukh, S.G. 2010. The competitiveness of SMEs in a globalized economy. *Management Research Review,* 33(1), 54-65.

Smart Market Report. 2013. *Bed ford,* MA: McGraw Hill construction.

UNESCO. 2010. *Guidebook for planning education in emergencies and reconstruction (section 1).* Paris: UNESCO International Institute of Educational Planning.

Wacker, J.G. 2004. A theory of formal conceptual definitions: developing theory-building measurement instruments. *Journal of Operations Management,* 22(6), 629-650.

Wal, R.D. and Marks, P. 2007. *Evaluation of capacity building projects in organizations in developing countries.* Doctoral Thesis. Erasmus University Rotterdam.

Womack, J.P. and Jones, D.T. 1996. *Lean thinking*. New York: Simon and Schuster.

Womack, J.P. and Jones, D.T. 2003. *Lean Thinking*.3rd ed. New York: Simon and Schuster.

Womack, J.P., Jones, D.T. and Ross, D. 1991. *The machine that changed the world: the story of lean production.* New York: Harper Collins.

WORK STRESS OF FACILITIES MANAGERS IN THE SRI LANKAN CONTEXT

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ABSTRACT

Work stress has become a global phenomenon in modern day workplaces. Sri Lankan organisations is no exception and Facilities Managers are increasingly encountering stress issues relating to work day by day. Facilities Managers work environment include both hard Facilities Management (FM) and soft FM functions which is complex and constrained by time, as they run to manage and support the operational functions of their core business. Hence the pressure on Facilities Managers to produce high quality results in limited time is severe. Thus, the impact of this would be reflected on organisation's core business through unwanted loss in terms of cost and low quality services due to workload. Therefore, it is vital to address this growing issue in order to survive in today's competitive world and cultivate a healthy profession with good ethical standards. This study focuses on work stress of Facilities Managers working in Sri Lankan organisations. A comprehensive literature review was carried out and identified the factors influencing work stress of Facilities Manager. Questionnaire survey and semi-structured interviews were used as two separate techniques to explore how work stress of Facilities Manager impacts performance in an organization and to identify the manageability level of stressors by Facilities Manager. Research findings revealed the common problems associated with work stress of Facilities Managers such as contradictory requirements placed at work, multi-disciplinary task, keeping the workplace on top shape, hardly hear good comments from end user and high quantitative demand of work, reasons behind them, and strategies to mitigate work stress, while addressing potential barriers in implementing those strategies.

Keywords: *Facilities Managers; Sri Lanka; Stressors; Work Stress.*

1. INTRODUCTION

In the final decade of the last millennium, the Facilities Management (FM) industry emerged as one of the fastest growing sectors (Reeves, 1999). Nowadays, the importance of FM is readily acknowledged in many companies which recognise the necessity of properly managing elaborate and expensive support facilities (Taylors, 1995). The tasks are multi-disciplinary and cover a wide range of activities, responsibilities, and knowledge, because every aspect of an organisation will come under the purview of FM. Kaya and Alexander (2005) suggested that organisations see FM as belonging to one of five areas; a property issue, a people issue, an operational issue, a hard cost issue or core to overall business success.

Facilities are second only to human resources as the largest 'asset' for an organisation, and the role of facilities manager is to ensure that the physical infrastructure is strategically aligned to the organisation's core business – incorporating financial, social and environmental objectives over the entire life cycle of property investment and ownership. The role is becoming critical as built infrastructure increases in complexity and value and has more pervasive social [and environmental] impact as a user of natural resources (Jane, 2007).

The FM industry encompasses a range of services. The 'hard' services (technical services, building services, etc.) and the 'soft' services (security, cleaning, etc.) are the general divisions of the industry. The reduction of the operational cost and focusing of their core business functions are done by using combined facilities support

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services. It organizes the workplace with the labour force, the public and work within it (Aston, 1994). Facilities Managers may perform various functions in an organisation including technical stuff and machinery operating. Therefore, they have to upgrade their knowledge continuously with the modern world, if not they will have to face issues regarding their jobs, which creates the basis for the stress.

Stress results from the interaction of the employee and the conditions at work. It occurs where demands made on individuals do not match the resources available or meet the individual’s needs and motivation (Jex, 1998). Further to the same author, stress will be the result if the workload is too large for the number of workers and time available. Equally, a boring or repetitive task which does not use the potential skills and experience of some individuals will cause them stress (Park, 2007).

Effective FM, combining resources and activities, is vital to the success of any organisation. Moreover, complex jobs create the work stress in high level. This is supported by Manshor *et al*. (2003), stating that employees may experience more stressful working conditions and feel pressured if they are instructed to do a more difficult job function and to take up responsibilities and when the work is perceived harder than the work done by other working teams. Adjustments required by an individual at work which necessarily sacrificing the needs of home fairs can course stress that may influence the performance and production of the entire organisation.

In the current context, FM has reinforced its importance in the sustainability of the business organization. Moreover, FM has a wider scope integrating people, place process and technology. Facilities Manager needs to engage in various tasks and take in-charge of emergencies ensuring the continuity of the business. FM is increasingly becoming an important function in the built environment. The workload for a Facilities Manager would be comparatively higher as they need to handle emergencies and ensure the business continuity, which will result in the stress for a Facilities Manager. Therefore, it is essential to identify the working stress of Facilities Manager for his better performance. Hence this research is conduct to investigate the stress level of Facility Manger in Sri Lankan context. Furthermore, it has carried out in accordance to stress level of FM in Sri Lanka in order increase the performance of Facilities Manager, which is an emerging profession in Sri Lanka.

2. WORK STRESS IN FM PROFESSION

Anderson and Sullivan (1994) stated that usually management must be a part of business resources however Facilities Managers have a great impact on strategic decisions and to demonstrate the contribution to achieve the business targets and goals efficiently and effectively. Therefore, FM is the very unique and essential function to the organisation.

When an organisation intends to respond the changing business practices, the current range and scope of facility activities need to extend the limits, such as providing technical solutions to problems arising, but to ensuring the facilities effectiveness is maximized and occupancy costs minimized (Meyer, 2003). McLennan (2000), recommended that the trend in work practices is towards more responsive working arrangements, global dispersal of work, and new multi-venue and multi-location ways of working. In the current workplaces will have a tendency to be more flexible, more people centred and more responsive (Grimshaw, 2007).

Regarding the practical scenario, now a days FM to organisations in all sectors of the economy is now increasingly recognised (Atkin and Brooks, 2000). The attraction of FM is becoming increasingly common as forward-looking organisations are beginning to realise FM as a function with clearly defined objectives, strategic and commercially oriented discipline (Laird, 1994).

In present moving world of technology Facilities Managers require a broad and diverse skill set, much more in line with management and business services. FM role meets the challenges and barriers that confront the organisation it is supporting, as an enabler (Lu, 1997).

2.1. RESULTS OF WORK STRESS

Various adverse resultants for personal and the workplace around the organisational level were identified through the many examinations and surveys due to the occupational stress (Park, 2007). The stress gives unwanted loss in terms of cost and weakness to the organisation and the individual (Ross, 2005). Organisation gets losses from the employee’s absenteeism, tardiness, poor communications, employee’s job satisfactions, employee sick, compensations etc. directly and indirectly due to the employee stress (Ekundayo, 2014). According to Quick *et al*., (1999), productivity reduction, diminishing levels of customer service, absenteeism, turnover, drug usage and other destructive behaviours are some examples for the adverse effects of occupational stress.

Consequences of occupational stress can lead to unwanted feelings and behaviours such as job dissatisfaction, lower motivation, low employee morale, less organisational commitment, lowered overall quality of work life, absenteeism, turnover, intention to leave the job, lower productivity, decreased quantity and quality of work, inability to make sound decisions, more theft, sabotage and work stoppage, occupational burnout, alienation, and increased smoking and alcohol intake (Shen and Sun, 2007). According to the International Labour Organisation (ILO, 2005) physiological problems have a considerable impact on the employer such as reduced productivity and lowered morale.

According to Karasek *et al*., (1988), the outcomes of occupational stress can result in significant economic and social costs for both employers and employees. Moreover, if not managed properly occupational stress may lead to increase in absentee rates, internal conflicts and low employee morale (Christo and Pienaar, 2006).

2.2. STRESS MANAGEMENT

There are a number of ways by which the risk of work stress can be reduced. Cox and Griffiths (1995) identified three major prevention methods such as primary prevention, secondary prevention and tertiary prevention. The primary prevention reduces stress through ergonomics, work and environmental design, and organisational and management development. The secondary prevention reduces stress through worker education and training and tertiary prevention reduces the impact of stress by developing more sensitive and responsive management systems and enhanced occupational health provision (Cox and Griffiths, 1995).

The organisation itself is a generator of different types of stresses. Moreover, Cox and Griffiths (1995), stated that a good employer designs and manages work in a way that avoids common risk factors for stress and prevents as much as possible foreseeable problems. It might therefore be better to identify any mismatch between demands and pressures, on the one hand, and workers' knowledge and abilities, on the other, set priorities for change and manage the change towards risk reduction (Fernet *et al*., 2004).

2.3. BENEFITS OF TACKLING STRESS

Kumar and Chakraborty (2013) mentioned that the benefits of tackling stress may include improved performance, increased productivity, sound wellbeing, enhanced organisational image, and improved employee retention, improved quality of life and so on. A cultural aspect was advocated by Friedman and Greenhaus (2000), where the authors state that a supportive work-family culture empowers psychological drive to confront problems and issues around the employees, which eventually attracts the employee to the job. This inherently creates a pleasant working environment for the entire work place.

From an employer's perspective, Hurley and Estelami (2007) stated loss of expertise, experience, knowledge and relationships can be reduced. Furthermore, quality of working life where employees feel happier at work and perform better, management of change which includes introducing a new pay system or new patterns of work is easier when stress is managed effectively, employment relations where problems can be resolved at work rather than at an employment tribunal and attendance levels go up and sickness absence goes down.

3. RESEARCH METHOD

The research initiated with a literature review to locate the common stress issues relating to work; and the importance of managing work stress in order to enhance their professional career. The survey approach was adopted as the best suitable method for the research among Facilities Managers working in Sri Lankan organisation to ascertain their perception on work stress issues and solutions to mitigate them. Sampling strategy for data collection was convenience sampling under non-probability sampling technique. Since it allows the researcher to pick samples representing various Facilities Managers who work in different working environment, it is more effective to analyse the time management issues and the techniques used to overcome those issues. Questionnaire survey was conducted to reveal the common problems associated with work stress of Facilities Managers, reasons behind them, and strategies to mitigate work stress, while addressing potential barriers in implementing those strategies based on respondents' comments on a 5 point Likert scale and semi-structured interviews were used to develop a guideline to mitigate work stress of Facilities Manager. Questionnaires were distributed among 62% Facilities Managers and semi-structured interviews were conducted among 3 experts having expertise in Facilities Management, Human Resource Management, and Psychology. Factorial ANOVA test (to consider the effect of more than one factor on differences in the dependent variable) was used to analyse data collected through questionnaire survey, and data collected through interviews were analysed using content analysis to arrive at suitable conclusions and recommendations.

4. DATA ANALYSIS

The data collected through questionnaire survey conducted among FM professionals practicing in Sri Lanka and semi-structured interviews conducted among practitioners having expertise with regard to this research topic. Presented data were analysed from various perspectives to understand the interrelationships between variables and underlying truths to demonstrate a clear understanding on the research findings.

4.1. PROFILE OF RESPONDENTS

Respondents of the questionnaire survey were FM professionals working across Office, Hospital, Factory, Condominium, Hotels and other organisations in the private sector, government sector and semi government sector and at different managerial positions and having different work experience respectively as identified in Figure 1, 2, and 3.

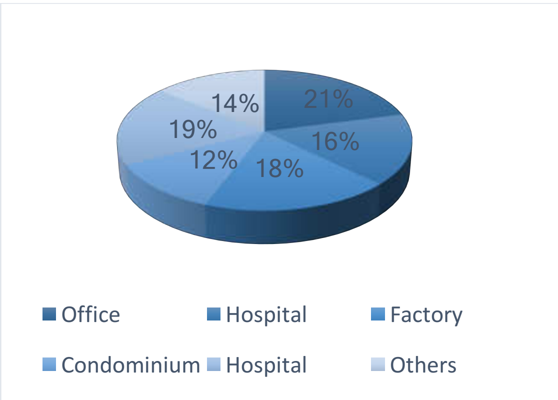

Figure 1: Respondent Profile Based on Types of Organisation

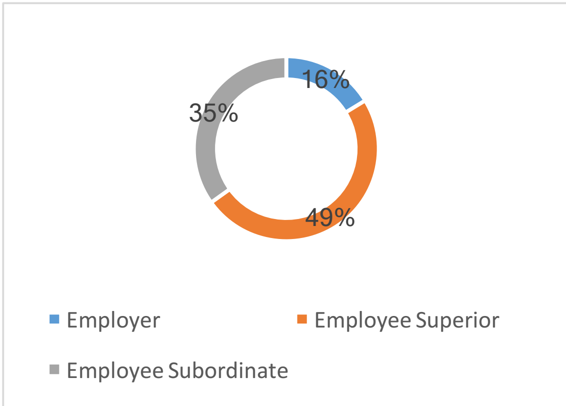

Figure 2: Respondent Profile Based on Managerial Position

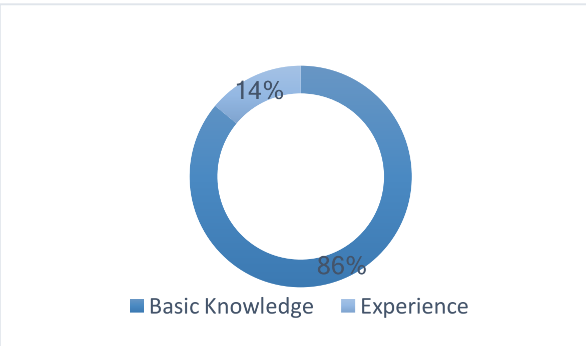

Figure 3: Respondent Profile Based on who Experience Issues in Relation to Work Stress the Most

4.2. ESTABLISHING THE PROBLEM OF WORK STRESS

The sample was verified to ascertain if the problem of work stress is evident in the sample so that conclusions could be drawn for the population. Figure 4 reports on the level of awareness of work stress among the sample and Figure 5 illustrates the perception of the Facilities Managers with regard to the severity of this issue in the Sri Lanka.

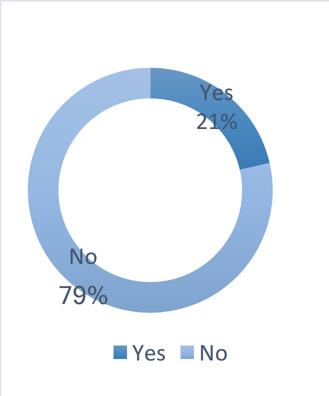

Figure 4: Awareness of Work Stress

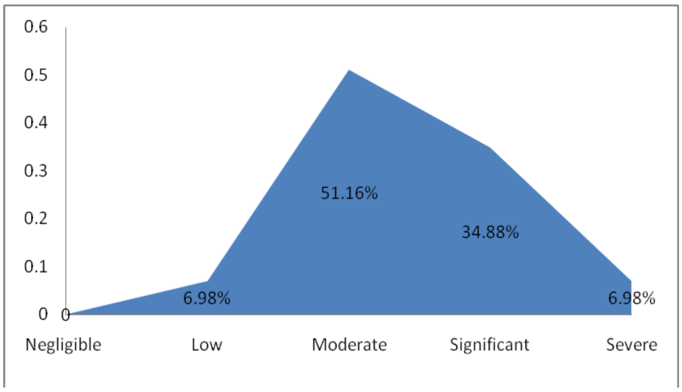

Figure 5: Severity of Work Stress Issue

Figure 4 provides conclusive evidence that 79% of the respondents in the sample have admitted the lack of awareness of work stress and Figure 5 proves the severity of work stress issues to be substantial with 93% of respondents rating the severity to be at a moderate to significant level. Based on the results on the sample it can be interpreted that the population has a serious issue on work stress. Therefore, the basic research problem of this study has been verified with the conformance from the Facilities Managers on existence of work stress to be significant although they are less familiar with the concept of work stress mitigation.

Having established the problem of work stress, the communication mechanism was used to identify the existence and to see whether these issues are brought to light by Facilities Managers working in organisations to their employer's/top management. Figure 6 illustrates the results of the respondents with regard to the method in which they came to know the existence of work stress. Figure 6 clearly states that most individuals have discovered work stress issues through personal experience which is approximately15% and the next majority being through discussion with peers approximately11.5%, followed by a small percentage of people through observation approximately 3.5%. A significant point has to be emphasised on the absence of a proper organisational communication mechanism in Sri Lankan organisations to report on work stress issues. This issue needs to be addressed by organisations in order to facilitate effective communication to implement solutions.

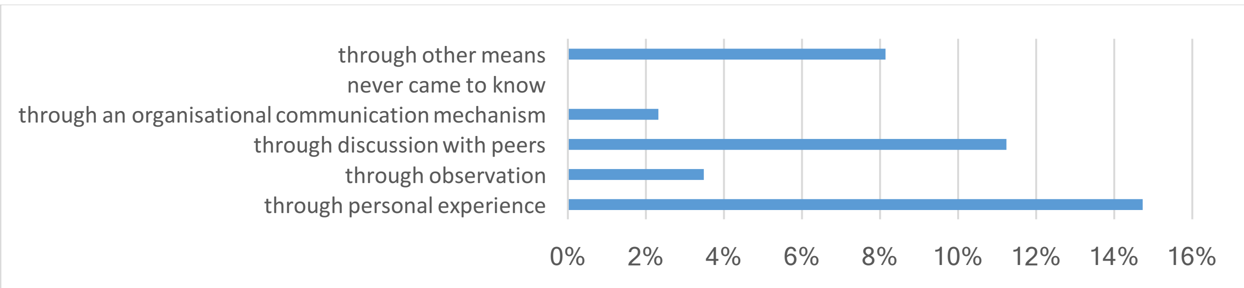

Figure 6: Communication Severity

4.3. ANALYSIS ON ISSUES PERTAINING TO WORK STRESS

Existence of work stress issues were analysed using a statistical tool, Factorial ANOVA (Analysis Of VAriance) in the statistical analysis package SPSS. The Factorial ANOVA test provides an estimated marginal mean value for each work stress issue based on respondents' comments on a 5-point scale rating. This will look like the Facilities Manager populations' perception on each issue and rank them accordingly giving priority to the top priority factors.

In addition to it, Factorial ANOVA is capable of testing the significance of each issue across varying categorical variables. For instance, in the given case of analysis, each issue is statistically verified whether work experience / the person experiencing stress the most have an effect on the issue. ANOVA will conduct an F test and give an F value along with the level of significance for the F value. The level of significance is also known as the p value (probability of occurrence of the event). A confidence interval of 95% was adopted based on rule of thumb, which means the benchmarking p value is 5% (0.05). If the p value for a particular issue is less than 0.05, it means a significant effect is caused by the categorical variable (work experience / the person experiencing stress the most) and vice versa. Statistically this is known as rejecting the null hypothesis H0: the particular factor does not have any significant effect on the issue or there is less than 5% chance that the result would have been due to random reasoning.

Table 1: Results of Factorial ANOVA for Work Stress Issues

Type of issue	**Estimated Marginal Mean**	**Work Experience in hard FM/soft FM/total FM**		**Experiencing stress the most**		**Rank**
		F	**Significance**	**F**	**Significance**	
Physical Issues						
Increased error in work / less productive	3.51	2.205	0.000	0.578	0.458	5
Unpleasant environment with employees	3.53	0.482	0.266	0.128	0.653	3
Burnout (Physical or mental collapse caused by overwork or stress)	3.53	0.413	0.082	0.506	0.000	3
Eating disorders (Skipping meals due to workload / priority to finish work before diet)	3.86	2.786	0.040	0.227	0.628	1
Psychological issues						
Less control over work	3.40	0.580	0.008	1.530	0.000	6
Lack of commitment	2.98	0.193	0.376	3.552	0.015	8
Depression and anxiety	3.60	1.213	0.004	1.154	0.000	2
Trouble sleeping/ insomnia	3.14	0.196	0.939	0.567	0.688	7

Table 2: Results of Factorial ANOVA for Reasons Behind Work Stress.

Reasons	**Estimated Marginal Mean**	**Work Experience in hard FM/ soft FM/ total FM**		**Managerial Position**		**Experiencing stress the most**		**Rank**
		F	**Significance**	**F**	**Significance**	**F**	**Significance**	
High quantitative demand of work	4.19	0.793	0.460	1.018	0.371	1.882	0.165	6
Excessive time pressure	4.30	0.940	0.399	0.258	0.774	0.501	0.610	2
Need to hit targets/deadlines	4.28	0.750	0.529	1.386	0.261	1.576	0.211	4

No separation/ distribution of hammering the responsibility (Facilities Manager has to take the responsibility)	4.40	0.541	0.290	0.093	0.330	1.060	0.401	1
Hardly hear good comments from end user	4.30	1.102	0.001	1.680	0.187	1.411	0.024	2
Contradictory requirements placed on you at work	4.05	2.145	0.110	0.767	0.520	1.187	0.327	7
Multi-disciplinary task	4.23	0.627	0.007	0.138	0.113	0.564	0.000	5
Handling emergency situations	3.95	0.444	0.162	1.326	0.584	1.257	0.019	10
Difficulty in integrating people, place, process and technology	3.98	0.531	0.029	0.896	0.264	0.770	0.265	9
Keeping the workplace on top shape	4.00	0.689	0.011	0.180	0.830	1.712	0.005	8

Table 3: Results of Factorial ANOVA for Solutions to Mitigate Work Stress

Solutions	**Estimated Marginal Mean**	**Work Experience in hard FM/ soft FM/ total FM**		**Managerial Position**		**Experiencing stress the most**		**Rank**
		F	**Significance**	**F**	**Significance**	**F**	**Significance**	
Steps which could be taken by the employer								
Adopt the style of a flexible firm	4.37	1.101	0.033	0.228	0.299	0.158	0.571	6
Support and understanding from superiors	4.28	1.137	0.002	0.704	0.545	1.841	0.000	9
Delegate work among employees to avoid workload affecting one individual	4.58	0.821	0.059	1.548	0.008	0.257	0.656	2
Provide regular and constructive feedback	4.33	0.475	0.022	1.293	0.407	1.657	0.158	8
Maintain adequate number of workforce to avoid work overload	4.44	1.185	0.003	1.468	0.220	1.701	0.168	3

Conduct job satisfaction survey and mid-year review	4.35	0.144	0.518	0.763	0.409	3.770	0.032	7
Provide right set of people with different layers of subordinates (Strong team)	4.67	0.749	0.038	1.840	0.335	0.489	0.248	1
Steps which could be taken by the employee								
Have positive attitude with dedication and self-control	4.44	0.204	0.512	2.480	0.736	0.306	0.005	3
Seek knowledge, do not assume the work until knowledge is gained	4.42	0.510	0.026	1.910	0.545	0.168	0.903	5

5. RESEARCH FINDINGS

5.1. OVERVIEW OF WORK STRESS

Analysis on survey findings revealed the lack of awareness about work stress mitigation policy among Facilities Managers in Sri Lanka. The underlying reason was figured to be the culture of the local community, where, by nature they are naïve to think about personal welfare over professional work. It is because the mentality of the local workforce gives high priority to work for a boss rather than individual space and does not concern much about their knowledge and workload. The corporate world has also held the employees in dark utilising this social character of Sri Lankan professionals and have not created enough awareness on work stress mitigation. The education system or state authorities also have not given any concern to this phenomena, which was revealed by experts in the interview.

Despite the lack of awareness on work stress mitigation policy, a vast majority of FM professionals confirmed the existence of work stress on their job to be very significant. Research problem of this study was confirmed through this acceptance.

5.2. ISSUES RELATING TO WORK STRESS AND REASONS BEHIND THEM

The existence of work stress among Facilities Managers is evident from physical, psychological, and societal issues. The significant issues were eating disorders, stress/depression and unpleasant environment with employees and burnout.

Other issues found in literature such as aggressiveness, impulsive behaviours, lack of job satisfaction, prevents exhibition of creative skills, unable to relax, tense more often feelings of powerlessness, less interest for work, lack of confidence in taking up challenges were not significantly present among Facilities Managers in Sri Lanka. Work experience in hard FM/soft FM/total FM and person experiencing stress the most influences the impact of these issues. Research findings clearly demonstrated that stress levels are high for Facilities Managers having basic knowledge rather than experienced in most of the reasons. Therefore, it is better to address this issue with some concern despite its unpopularity, since its effects could be extremely hurtful.

When considering reasons for work stress, no separation/distribution of hammering the responsibility was accepted unanimously by the Facilities Managers as one of the prime reason for work stress. The other significant reasons that were identified through research findings were hardly hear good comments from end user, excessive time pressure, need to hit targets/deadlines, multi-disciplinary task, high quantitative demand of work, contradictory requirements placed at work, keeping the workplace on top shape; the reasons were uniform across experiencing stress the most and across work experience in hard FM/soft FM/total FM, except for handling emergency situations, integrating people, place, process and technology. It is because only employee superior has practices available to trigger these issues.

5.3. PRACTICALITY OF WORK STRESS MITIGATION INITIATIVES

The problem of work stress among Facilities Managers career was attempted to solve from two perspectives. One being the initiatives from the individual himself and the other being initiatives from the organisation employee is attached to. New methods in addition to those prescribed in literature were found through the expert interviews. The questionnaire survey was good enough to validate the practical applicability of work stress strategies found in the literature to the Sri Lankan context.

Analysis on research data proved positive attitude with dedication and self-control with respect to work and strictly adhering to it, and seeking knowledge and understanding from superiors to be the most valid practical strategies that could be followed by an individual. These two strategies were also backed by the experts in their interviews. Particularly having a good superior could help Facilities Managers reduce their work stress situation due to the understanding and care from their counterpart. This idea was stressed by the psychological expert to be a more vibrant strategy. However, for it to be effective the individual’s counterpart has to be approachable to hear his problems. If there is a mismatch between the pair this strategy would not work but rather flop.

Focusing on a broader perspective organisation can provide right set of people with different layers of subordinates (Strong team), delegate work among employees to avoid workload affecting one individual, provide timely information to enable staff to understand the reasons for the change, provide regular and constructive feedback, conduct job satisfaction survey and mid-year review and maintain adequate number of workforce to avoid work overload affecting one individual. However, for all these strategies to take effect, the culture of the organisation has to be changed to support and care the work stress of employees.

Having analysed the initiatives for work stress mitigation from both perspectives, it is important to discuss each party’s contribution. Individuals should be independent of the organisation and formulate work stress mitigation policies to suit their personal requirements and life style. This proves to be more effective and has less chances of affecting the organisation in a negative manner. To reach a truly successful balance in work and entire society individual effort alone would not be sufficient. Therefore, organisations also should join hands in creating policies at work place to support work stress mitigation initiatives. Moreover, it is extremely crucial for Sri Lankan to focus on this matter. Role of government with regard to this whole issue was excluded for detailed analysis since it could indirectly support to enhance the balance of individuals.

In fact, the initial strive from corporate heads towards work stress mitigation policies, lack of demand from employees for such policies, management of the firm not encouraging work stress mitigation initiatives and personal incapability of developing individual strategies could be the potential barriers that could prevent in implementing the strategies identified. Hence, these barriers need to be eradicated or at least weakened for the strategies to take effect.

6. CONCLUSIONS

The research has captured Facilities Managers having their professional practice in Sri Lankan organisations. The nature of work of the profession and the current lifestyle of those professionals as average Sri Lankans, creates great challenge in reducing the work stress. Hence, first of all every individual should try their best to adopt strategies to reduce the work stress they encounter and strictly stick to it. However, for an individual to follow a strategy the environment they work and knowledge they are having should be favourable for them. This highlights that they should possess in breadth knowledge and practical skills in some specific filed. Therefore, they should take initiatives to develop a good practical knowledge to work. If there has been a problem encountered it has to be taken in to account by Facilities Manager and has to be discussed with the superior who is having experience in various fields and a proper solution should be taken as soon as possible. It has been reported that lack of proper organizational communication mechanism was the major reason for the work stress being unnoticed.

7. REFERENCES

Anderson, E. and Sullivan, M., 1994. The antecedents and consequences of customer satisfaction in firms. *Marketing Science*, 12(2), 125-143.

Aston, L., 1994. Appraising contracting options. In Alexander, K. Ed. *Facilities Management*, University of Strathclyde: Glasgow.

Atkin, B. and Brooks, A., 2000. *Total facilities management*, London: Blackwell.

Christo, B. and Pienaar, J., 2006. South africa correctional official occupational stress: The role of psychological strengths. *Journal of Criminal Justice*, 73-84.

Cox, T. and Griffiths, A., 1995. The nature and measurement of work stress: Theory and practice. In J. R. Wilson and E. N. Corlett, eds., *Evaluation of human work: a practical ergonomics methodology.* London: Taylor and Francis.

Ekundayo, J. A., 2014. Occupational stress and employees' productivity in the workplace. *International Journal of Scientific Research in Education.*

Fernet, C., Guay, F. and Senecal, C., 2004. Adjusting to job demands: The role of work self determination and job control in predicting burnout. *Journal of Vocational Behaviour,* 65(1), 39-56.

Friedman, S. and Greenhaus, J., 2000. *Work and family - Allies or enemies? What happens when business professionals confront life choices.* New York, NY: Oxford University Press.

Grimshaw, B., 2007. History is bunk: Considerations on the future of FM. *Facilities*, 25(11), 411 – 417.

Hurley, R. and Estelami, H., 2007. An exploratory study of employee turnover indicators as predictors of customer satisfaction. *Journal of Services Marketing*, 21(3), 186-199.

International Labour Office, 2005. *Mental health in the workplace.* Geneva: International Labour Office.

Jane, F., 2007 An Overview of Facilities Management. *Dusseldorp Skills Forum*, pp 2-25

Jex, S., 1998. *Stress and job performance.* Thousand oaks, CA: Sage.

Karasek, R., Brisson, C. and Kawakami, N., 1988. The job content questionnaire (JCQ): an instrument for internationally comparative assessment of psychosocial job characteristics. *Journal of Occupational Health Psychology,* 3(4), 322-355.

Kaya, S., and Alexander, K., 2005. Classifying FM organizations using pattern recognition. *Facilities*, 23(13/14), 570-584.

Kumar, H. and Chakraborthy, S., 2013. Work life balance: A key organisational efficiency. *A Peer Reviewed Research Journal,* 15(1), 62-70.

Laird, S., 1994. Total facilities management. *Facilities*, 12(13), 25-31.

Lu, L., 1997. The process of work stress: A dialogue between theory and research. *Chinese Journal of Mental Health,* 19-51

Manshor, A. T., Fontaine, R. and Choy, C. S., 2003. Occupational stress among managers: A malaysian survey. *Journal of Managerial Psychology*, 18(6), pp. 622-628.

McLennan, P., 2010. FM structures: Introduction to Facility Management, London: University College.

Meyer, M., 2003. Translating empty space into dollars: How to get a handle on space, its use and its real cost. *Facility Management Journal*, 29-30.

Quick, J. C., Quick, J. D., Nelson, D. and Hurrell, J., 1999. *Preventive stress management in organisations.* Washington, DC: American Psychological Institute.

Reeves, R., 1999. Repositioning FM: Meeting the business imperatives for fundamental change. In: *Future in Property and Facility Management*. London: University College London, p. 19.

Ross, G., 2005. Tourism industry employee work stress - A present and future crisis. *Journal of Travel and Tourism Marketing*, 19(2-3), 133-147.

Shen, X. W. and Sun, L. Z., 2007. A Review of Research on the Occupational Stress in Western Countries. *The Border Economy and Culture,* 47(3), 74-76.

Taylors, S., 1995. *Managing people at work*. London: Reed Educational and Professional Publishing

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