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THE THIRD WORLD CONSTRUCTION SYMPOSIUM

Sustainability and Development in Built Environment: The Way Forward

THE SECOND CONSTRUCTION INDUSTRY INVESTORS FORUM

Seizing Opportunities in the Sri Lankan Construction Industry Boom

Sustainability and Development in Built Environment

20 - 22 June 2014 - Colombo

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PROCEEDINGS

THE 3RD WORLD CONSTRUCTION SYMPOSIUM

2014

Theme

Sustainability and Development in Built Environment: The Way Forward

Editors

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We would like to express our appreciation towards the Ceylon Institute of Builders (CIOB), for inviting Building Economics and Management Research Unit (BEMRU) of the Department of Building Economics, University of Moratuwa to jointly organise this symposium for the third time and assigning us the major task of paper administration. We also extend our sincere gratitude towards the main sponsor of the symposium, the International Council for Research and Innovation in Building and Construction (CIB) and the associate partners: Glasgow Caledonian University, UK; Liverpool John Moores University, UK; and Center of Infrastructure and Construction Industry Development, The University of Hong Kong for their constant support.

We are very thankful to the authors who have submitted papers for this symposium, as if not for them, we could not hold this event. Next, our thanks go to the eminent international and local scientific committee members for reviewing and offering constructive comments to make the papers more meaningful and contextual. We would like to extend our gratitude towards the chief guest, keynote speaker, session chairs and coordinators, paper presenters, industry presenters, members of panel discussion and investor forum, awards selection committees, BEPAM journal editor-in-chief, Emareld publisher and the committee and other invitees for their commitment and contribution to the symposium.

We are also thankful for the organisations that have provided sponsorships. Last but not least, all our colleagues in the organising committee are especially thanked for devoting their time and effort to make 'The 3rd World Construction Symposium 2014' a success.

Editors
The 3rd World Construction Symposium 2014
Sri Lanka
June 2014

PREFACE

The 3rd World Construction Symposium 2014 held on 20 - 22 June 2014 in Colombo, Sri Lanka is jointly organised by the Ceylon Institute of Builders (CIOB) and Building Economics and Management Research Unit (BEMRU), Department of Building Economics, University of Moratuwa. International Council for Research and Innovation in Building and Construction (CIB) is the main sponsor of the event. Glasgow Caledonian University, UK; Liverpool John Moores University, UK; and the Center of Infrastructure and Construction Industry Development, The University of Hong Kong are the associate partners of the Symposium. The main theme of this international symposium is '*Sustainability and Development in Built Environment: The Way Forward'*. The symposium will provide a special forum for academic researchers and industry practitioners to share their knowledge, experience and research findings envisioning sustainable future in construction industry.

The sub themes of the symposium covers a wide spectrum of areas such as: Green Buildings; Sustainable Urbanisation; Sustainable Construction Practices; Innovative Green Technologies; Sustainable Procurement Strategies; Environmental Economics and Management; Affordable Sustainability; Socio-Economic Sustainability; Sustainable Materials/Green Building Materials; Green Rating and Certification; Energy Management; Legal Aspects Relating to Sustainable Construction; Sustainable Facilities; and Education of Sustainable Construction.

We received number of abstracts and full papers for the symposium covering the above themes. All full papers went through a rigorous double-blind peer-review process by a well qualified panel of international and local reviewers with respect to the originality, significance, reliability, quality of presentation and relevance, prior to selection. 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 and that it would pave way for advancement of knowledge in sustainability and development in built environment.

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A CRITICAL REVIEW OF WATER STUDIES IN CONSTRUCTION INDUSTRY

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ABSTRACT

Water is not only a basic need of human beings, but also a strategic economic resource. However, the distribution of water throughout the earth is diverse. At present, water is a challengeable natural resource for many countries and some studies predicted that the world will face a water dilemma in 2025-2030, if not consumed in sustainable way. Moreover, population growth, climate change, and industrialisation are critical factors that impact on the water sector and ultimately result in freshwater shortage and continued water pollution. The current practice considers water as a separate sectoral box in many economic evaluations although water is an integrated resource in many industries. Therefore, the time has come to think out of the box with the cohesiveness of sustainable development. It is a known fact that the construction industry too uses water in almost all the activities and without water no more construction is possible. However, water management during construction is given less attention by the industry stakeholders at present. This is despite an upsurge in the demand for construction activities both in building and civil engineering projects due to speedy industrialisation to cater for the population growth. This paper is based on the literature review of an on-going PhD research. The paper critically reviews the secondary data on water studies conducted in the construction industry. The views and findings on water handling during the physical construction, and strategies towards sustainable water consumption in construction industry are also discussed. In addition, the paper identifies four critical drivers that impact on sustainable practices of water use during the physical construction phase.

Keywords: *Construction Industry; Sustainable Use; Water Efficiency; Water Resource.*

1. INTRODUCTION

Water is different from other natural resources. As Chellaney (2013) states, there are substitutes for many resources including oil, but none for water. Similarly, countries can import fossil fuels, minerals and resources from the biosphere, but hardly import water, which is essentially local. With reference to the literature available on water resource, substantial growth in population, industrialisation and potential future climate change such as global warming will exacerbate the demand for water. Joyce (2012) states that, the difference between increasing demand for water and limited water availability creates a gap that is translated into water scarcity. However, limited freshwater is a major constraint on sustainable development (Khalfan, 2002; Horne, 2012). This implies the requirement of sustainable strategies for better management of water resource in all the sectors. Construction industry is one of the main pillars of economy in any country. It consumes large amount of natural resources including water. Hence, construction activities always have the potential to affect the surrounding environment. Strategic Forum for Construction Water Group reports that relatively little work has been carried out to date on water sustainability at construction sites (Waylen *et al*., 2011). On the other hand, water conservation is received relatively low priority in comparison to the focus on reducing waste and improving the carbon footprint. The Strategic Forum for Construction Water Subgroup highlighted some issues of water use in the construction activities and identified number of targets pertaining to the more efficient use of water and water usage on construction sites (Waylen *et al*., 2011). Many researchers emphasise the requirement of establishing water saving policies, guidelines, concrete actions and technologies to reduce water consumption and wastage during the construction (McComack *et al*., 2007; Houser and Pruess, 2009; Sala *et al*., 2013). Therefore, the paper aims to critically review the previous studies, which were carried out in the construction industry in terms

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of water handling, monitoring, conservation, and strategies that adopted during the physical construction phase. In addition, the paper will discuss critical drivers that will impact on sustainable practices of water use during the construction. In this study, the terms 'construction' and'construction phase' were used to explain the physical construction works from the whole project life cycle.

2. RESEARCH METHODOLOGY

Research methodology is a systematic and scientific way of solving any research problem. Therefore, it is vital to choose the appropriate research methodology in order to establish clear links between the research objectives and the research outcome. As Tan (2002) says, if research is to be systematic, it should follow a series of steps which is called as the research process. Thus, as in any research work, conducting a systematic literature review enriches and reinforces the research process initially. Iqbal (2007) explains that literature review is required to identify any gap in the knowledge and a successful researcher claims a gap in the existing knowledge with evidence. This paper is based on the comprehensive literature review of an on-going PhD research. Thus, findings of comprehensive literature review presented the consequences of water resource in the purview of sustainability, its application in construction industry and then identified few sustainable drivers which impact on sustainable water use during the construction phase. Finally, the paper elaborates the existing research done and way forward. Mainly, literature evidence was taken referring journal articles, books, published and unpublished bibliographies, conference proceedings, industry reports and documents. During the literature survey, key terms such as water efficiency, water consumption, conservation, quality, sustainability, and construction were used for review.

3. WATER RESOURCE IN THE PURVIEW OF SUSTAINABILITY

3.1. WATER AS A DEMANDING COMMODITY

This is a known factor that ninety - seven per cent of all the water on the earth is salt water which is not suitable for drinking and even for some construction activities. Only three per cent of all the water is fresh water, and from that only one per cent is available for drinking water. The other two per cent is sealed in frozen ice and cannot be easily accessed. Donge *et al*., (2008) clearly illustrate the distribution of earth's water as shown in Figure 1. Therefore, all the people on the earth are relying on such a small percentage of all the water on earth. This only makes sense the importance of preserve and conserve of the natural gift to sustain for future generation. However, still many people in the world feel water as an unlimited resource and considered as a cheap commodity because of that value of water as a commodity is hidden in many consumptions.

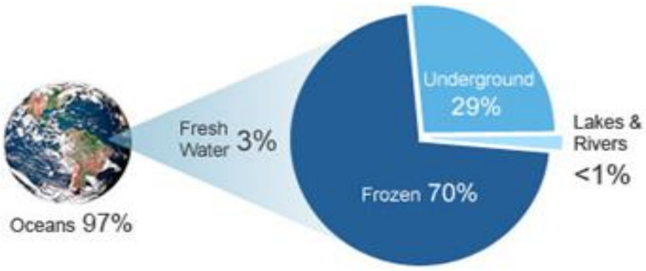

Figure 1: Distribution of Earth's Water
Source: Donge *et al.* (2008)

However, Donge *et al*., (2008) mention, pollution and contamination are a significant threat to water supply. On the other hand due to industrial expansion around the world, demand for water is rising at an alarming rate. Moreover, Biswas (2004) explains, water problems of the world are neither homogeneous, nor constant or consistent over time. They often vary significantly from one region to another, even within a single country, from one season to another, and also from one year to another. This statement is further supported by Figure 2 and 3 on some water demand statistics available. Figure 2 illustrates the forecasted figures on global water consumption with the global population. It shows the differences between the two values go up. Further, Figure 3 elaborates Asia's future water demand. This clearly indicates the tremendous increase of water demand in Asia compared to other regions.

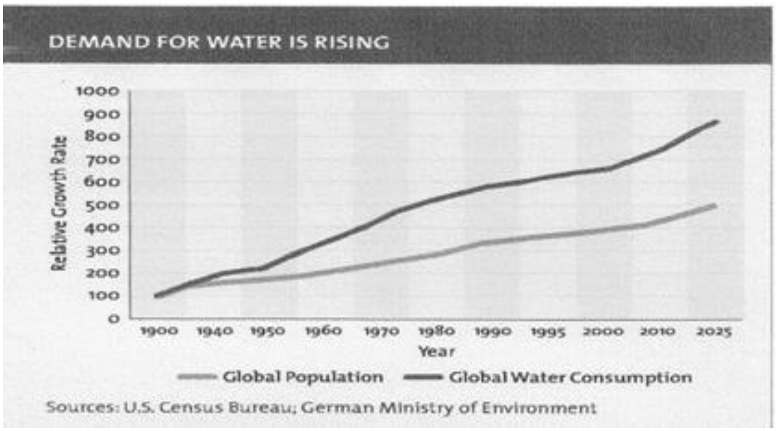

Figure 2: Demand for Water
Sources: adapted from Donge et al. (2008)

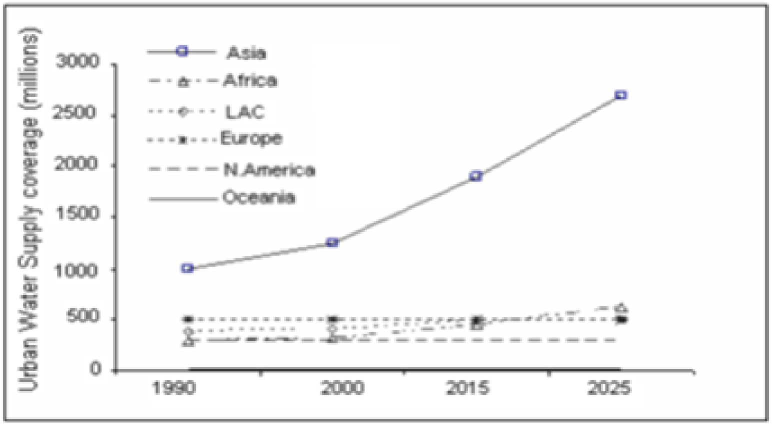

Figure 3: Asia's Future Water Demand
Source: Corcoran *et al*. (2010)

Sala and Wolf (2013) point out that industrial production and many services depend on continuous availability of freshwater and it is directly a threat for supplying safe drinking water in future. Moreover, the global water intelligent (2010 cited Rayan *et al*., 2013) forecasted there is a strong growth in global water industry spending capital expenditure in next few years on water infrastructure (6.5%), wastewater treatment (7.8%), desalination (8.6%), and recycling (9.4%). These facts well supported to establish water is a highly demanding commodity for the world in near future. As Zbigniew and Kundzewicz (1997) claim, water shortage is therefore likely to be the most dominant problem in the forthcoming century, jeopardising sustainable development.

3.2. WATER IN THE PURVIEW OF SUSTAINABILITY

The term sustainability can have different meaning to different people as well as to different discipline. However, any sustainable actions protect, preserve, and restore the integrity of the earth's life support systems. As Abidin (2009) mentions, sustainable development philosophy was introduced in 1987 in the Brundtland report and subset to this philosophy is sustainable construction. Water is an integral part of the ecosystem, a natural resource and a social and economic good (Zbigniew and Kundzewicz, 1997; Gleick, 1998). The European commission scientific and policy report mentions that water is more than an archetypal resource for which sutainability assessment is needed in order to preserve quality and quantity of the resource for present and future generations (Sala *et al*., 2013). Therefore, reducing water consumption and protecting water quality are key objectives of sustainable construction. Gleick *et al*. (1995 cited Gleick, 1998) offers a working definition of sustainable water use as "the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle or the ecological systems that depend on it". This paper refers ***sustainable use of water*** as minimise and eliminate unnecessary water use and wastage with minimal damage to the environment, society and to the economy.

Zbigniew and Kundzewicz (1997) explain that the availability of water in adequate quantity and quality is a necessary condition for sustainable development. In addition, knowledge and understanding of freshwater resources is also essential for sustainable development. Therefore, hydrological observations should be recognised as an essential component of sustainable water resource development. Robert *et al*. (2006) recognise that when actual amount extracted was below the sustainable level of extraction it was not a problem but over-extraction and subsequent overuse of river systems provide significant pressure. Gleick (1998) mentions that sustainability criteria layout specific social goals that could, or should be attained and offer some guidance for future water management. Further, The European commission scientific and policy report highlights requirement of generating concrete actions that will result in more sustainable consumption styles and patterns than awareness about the environmental consequences of human consumption behaviour for water resource (Sala *et al*., 2013).

The desired endpoints described in the UN and UNSGAB (2011) stressed that no country can meet its development objectives without improving the way it manages its water since water allocation to various economic sectors is a difficult exercise, and huge water wastage along with the supply chains. As Devaraja (2013) expresses, water losses may form of either apparent loss (physical- water leaks in pipes) or real loss (Non-physical- illegal consumptions, errors of measuring apparatus, administrative losses and free water supply). UN and UNSGAB (2011) highlights that if the demand for energy increases the demand for water will also rise and need to have an effective water pricing system. Similarly, Savenije and Van der Zaag (2002) state that having a price for water will give a clear signal to the users that water is indeed a scarce good that should be used sparingly. Moreover, it will stimulate conservation, may curb demand and encourages the use of water for high value uses.

4. WATER INPUT IN THE CONSTRUCTION INDUSTRY

4.1. THE CONSTRUCTION INDUSTRY

The nature of the construction industry is large, dynamic, and complex. It plays an important role in the economic growth of a country (Hussin *et al*., 2013). Construction work involves buildings, engineering (civil) projects, renovation, alterations, or maintenance and repair of building or civil projects (Behm, 2008). In general, the construction industry differs from other industries based on the products, stakeholders, processes, and the operating environment. Chen (1998) argues that there could be no economic activity without construction. Construction industry is a major contributor to economic growth (Chan, 2009). It has strong linkages with other sectors of the economy (Chen 1998; Rameezdeen *et al*., 2008). In Sri Lanka, according to the central bank report (2013), construction industry contributes 8.7% to the Gross Domestic Product (GDP) of the country. Spence and Mulligan (1995) mention the construction industry causes significant environmental stress. It is a known factor that construction of a building uses a lot of energy, water, and other resources throughout the construction life cycle that is pre-construction, construction and post-construction. Crawford and Pullen (2011) recognises that buildings are directly responsible for only around 12 percent of global water consumption through the production of building materials, construction and other supporting processes.

Guggemos and Horvath (2006) explain that although construction phase is shorter, the impact is more significant and if construction phase is neglected, the associated processes and materials are not optimised for environmental performance. Therefore, many researchers are concerned about how to improve construction practices in order to minimise the negative impacts on the natural environment (Holmes and Hudson, 2000; Cole *et al*., 2005; Pahwa, 2007; Hussin *et al*., 2013). As global interest on sustainability has grown steadily (Abidin, 2009), recently, the concept of sustainable or green building construction has come to the forefront of the construction industry. Hussain *et al*., (2013) mention green building practices are environmentally responsible and resource efficient throughout the buildings' life cycle. With that scenario, green or sustainable building rating systems which provide an effective framework for assessing building environmental performance and integrating sustainable development into building and construction processes (Cole, 2003 cited Ali and Nsairat, 2009). According to the findings of Waidyasekara *et al*., (2013), in terms of water efficiency addressed in building project life cycle, the priority given for the water consumption during the physical construction phase is ignored by many green rating systems including Green[SL]. For instance, in Abu-Dhabi, construction works completely depends on the desalinated water, however, no credits have been allocated for water monitoring and handling during the construction phase in the Pearl building rating system (PBRS). Whereas, rating systems Green Rating for Integrated Habitat Assessment (GRIHA) in India and Building Research Establishment's Environmental Assessment Method (BREEAM) in the UK have given credential for water sustainability during the construction. Waidyasekara *et al*. (2013) argue that need for a better sustainability assessment for water handling during the physical construction phase. Next section explains the views and key findings of water related studies conducted in the construction industry.

4.2. WATER STUDIES IN THE CONSTRUCTION INDUSTRY: VIEWS AND RESEARCH FINDINGS

It is widely documented, water studies in many sectors in terms of management, reuse, and recycling. However, strategic forum for construction water subgroup reports that relatively little work has been carried out to date on water sustainability on construction sites although water used for different activities and processes at the construction project level (Waylen, *et al*., 2011). The sections 4.2.1 and 4.2.2 reflect views and key research findings that conducted on water resource management in construction industry.

4.2.1. VIEWS ON WATER USE ON CONSTRUCTION SITES

Table 1 documented some views made by researchers regarding the body of knowledge exist in terms of water resource management in construction industry.

Table 1: Views on Water Use on Construction Sites

Views On Water Use in Construction	**Source of Reference**
Current knowledge of where water is used on construction sites and the volumes involved are limited during the construction lifecycle.	Waylen *et al*. (2011)- SFfC
Impacts from the construction phase are ignored or simply approximated, because the analysis is complicated or the impacts are thought to be small.	Guggemos and Horvath (2006)
Significant water quantity is consumed in the extraction, production, manufacturing, delivery of materials to site and the actual on-site construction process during buildings operation- i.e. embedded water	McComack *et al*., (2007)
Quality and quantity of water are important parameters that impact on strength of some construction works. Some concrete strength has failed due to wrong water cement ratio added in the mix.	Utraja (2010)
With the global warming, it requires more attention and investigation to save water and reduce water footprint for goods and services	Ilgar (2011)
By overcoming challenges such as value for money, work environment and habit, it was suggested water use on construction can be reduced.	Waylen *et al*., (2011)- SFfC
Amount of water consumed by the construction is unknown and not adequately measured	Goodrum (2008)
Requirement of establishing water saving policies, guidelines, concrete actions and technologies to reduce water consumption and wastage during the construction. Inappropriate incentives and institutions often hinder effective use of water during the construction.	McComack *et al*., (2007); Crawford and Pullen (2011); Houser and Pruess (2009); Sala *et al*., (2013)
Certain construction activities use water cause impact on the cost of energy	Waylen *et al*. (2011)- SFfC
Price increase of water used for construction remains unknown and requirement of changes to the water tariff system.	Goodrum (2008); Savenjije and Van der Zaag (2002)

According to Table 4, many scholars highlighted and are convinced that the requirement of future studies need to be addressed in the subject area. In other words, the attention paid on such research work is limited. Waidyasekara *et al*. (2012) state, there exist a vacuum in the area of water management body of knowledge in the construction industry compared to other industries. Apart from the views emphasised by some authors, Section 4.2.2 discusses the findings of some water researches that conducted in the construction industry through the comprehensive literature survey available in the built environment.

4.2.2. RESEARCH FINDINGS

The strategic forum for construction (SFfC) water subgroup in the UK is conducting series of research studies on water usage on construction sites. The group is made up of key representatives from the construction and manufacturing industries and the regulatory agencies such as the Environmental agency. Nine case studies were selected by the strategic forum for construction group (SFfC) to observe the construction water management process (Waylen *et al*., 2011).During the survey, discussion had with contractors and construction site employees, and the following key water using processes on construction on sites were identified.

- Sites cabins and temporary accommodation
- General site activities including tool washing
- Wet trades, such as brickwork, screeding, concreting and plastering
- Groundwork, including road and wheel washing
- Hydro- demolition
- Cleaning of tools and plant equipment, lorry washing
- Commissioning and testing of building plant and services
- Domestic and welfare water consumption

In addition, during the survey, it was found that water requirement is unique at construction sites. Among the water using activities, dust suppression, cleaning, commissioning and testing and domestic and welfare were identified as high water using activities. It was found good housekeeping that is reporting/repairing leaks, turning off taps which can assist construction sites to reduce its overall water use. Furthermore, creating a culture within the construction sector that changes staff's attitudes and behaviour to accept ownership of water efficiency is fundamental in improving the use of water in an efficient manner. However, during the survey, none of the sites audits were able to provide evidence of providing their site staff with regular awareness training on water efficiency. As a solution it suggested three strategies such as value for money, work environment and habit to reduce water usage on construction sites.

The result of seventeen non-residential case studies conducted by McComack *et al*., (2007) in Australia identify that considerable amount of water is embodied in construction. Moreover, it was found that the water embodied in building materials was significant, particularly steel, concrete and carpet. Ilgar (2011) also identifies steel production seems to consume higher amount of water compared to other building materials and the estimated total amount of water used for producing 4.06 million tons of steel is 12.18 [million m^3/year]. Greenroads™ manual v1.5 (n.d) specified cement production relies heavily on water as well in road and building construction. In addition, concrete mixing, concrete curing, dust control, construction equipment washing, vegetation establishment, geotechnical boarings, adding water to backfill materials/soil compaction, pipe flushing and pressure testing, and site clean-up are other on site construction water uses in both road and building construction projects.

On the other hand, the Queensland Government (2007) identifies dust suppression, cleaning, slurry work, pressure washing of concrete and other surfaces, concrete cutting, pressure test of water lines, washing construction vehicles before leaving the site, and increasing a soil's water constant for compaction as some of the activities that use water in construction projects. One of the studies conducted by SFfC of Waste and resources action programme (WRAP) on water audits on construction sites in the UK, it was found that the largest barrier to improve water efficiency on site was the lack of quantitative information due to the use of unmetered stand pipes and a faulty water meter. Thus they have suggested to utilise robust metering and monitoring system on site to overcome the identified issues (Waylen *et al*., 2011).

Further, the SFfC group proposed the water hierarchy which can be used during the physical construction. The water hierarchy shows how to prevent or reduce use of potable water through alternative sources, reuse and recycle. Fernando (2007) shows that applying 're-use' concept in the batching plant process, $2m^3$ per day can be re-used. This result derived through one case study conducted in Sri Lanka and the water used for cleaning the batching plant is subjected to filtering process and reuse for concrete production. Implementation of stages of water hierarchy during the physical construction phase from beginning to end is one of the significant areas however that have not been studied in depth so far. With regard to water sources for construction work, Greenroads™ manual v1.5 (n.d) identifies, natural water bodies, potable water supply pipe lines, and storm water as usual sources for construction work. Waidyasekara *et al*., (2012) claim that many construction projects get water for the construction works through public main especially around the urban areas in Sri Lanka. Although, drinking water or potable water is subject to competing demands by human, at present demanded by the construction industry too. Some construction activities need potable water standards. For instance concreting, rendering, and curing works. On the other hand, such standards are not required for activities like cleaning, washing vehicles, tools, and dust controlling. Ramachandran (2004) mention that one of the structural engineers Dr. A.R. Santhakumar in India said that if contaminated water is used, the life of the structure comes down from about 60 years to about 20 years. Unfortunately, yet many builders do not realise the importance of that and hence quality comes down. Further, the above named engineer mentioned that in normal construction, the water demand is roughly 10 to 20 percent of the volume of brick and concrete used. However, this can be reduced by modern techniques and recommends a more steel intensive construction. The vice president and head of Larsen and and Turbo Limited in India explains that the construction of a 100,000 sq. ft. multi-storey structure requires about 10 million liters of water for production, curing and site development activity and also a double lane flyover can consume 70 million liters of water on the similar scale (Ramachandran, 2004). Furthermore, he claims that the water shortage in Chennai was leading to delays in work and was increasing the unit cost of construction.

It was found that limited studies conducted on water resource management in construction industry by organisations and individual researchers although plentiful number of water researches available in other sectors. Cost of water is relatively cheap compared to the total project construction cost may be a reason behind that scenario. However, Hussin *et al*., (2013) identify construction industry as one of the largest polluters to the environment. Although, cost of water is insignificant yet, by considering future dilemma in the water resource it is pertinent to make correct decisions at the proper time in the construction industry since it is considered as a water intensive industry. Thus, the study identified many aspects which can impact to enhance the sustainable water practices during the construction will be controlled by the project itself and external entities based on the literature search. Considering each aspect, the authors identified four drivers namely, managerial, economic, environmental and social. The next section elaborates each driver with a brief explanation.

5. DRIVERS FOR ENHANCING SUSTAINABLE WATER PRACTICES DURING CONSTRUCTION

Bourg (2010) defines water efficiency is the planned management of water to prevent waste, overuse, and exploitation of the resource. Effective water efficiency planning seeks to "do more with less" without sacrificing comfort or performance. There are number of strategies that can be employed to reduce the amount of water consumed. Aforementioned literature findings proved that requirement of sustainable practices in order to enhance the water efficiency from beginning to end of the construction project. It is well known, protection and conservation of natural resources is one of the fundamental principles concern in sustainable construction. Therefore, incorporating sustainable practices ensure positive impact on communities throughout the nation. Like in many other sectors, efficiency of water use in construction can be done at two stages. That is during the project level and the national level. US Environmental protection agency (2012) divided water efficiency practices into two categories as (i) engineering practices which is based on modifications in plumbing, fixtures, or water supply operating procedures and (ii) behavioural practices which is based on changing water use habits. After the critical literature review, the following four drivers identified in order to enhance or uphold the sustainable water practices during the physical construction as shown in Table 2.

Table 2: Drivers for Enhancing Sustainable Water Practices during the Construction

Drivers for Sustainable Practices	**Description**
Managerial drivers	This explains the project specific drivers which are directly linked with the construction management process. A sheer number of project specific documents are available to control the project performance at different stages (e.g. conditions of contract, specifications, bills of quantities, construction program, sustainable rating system etc.). According to the guideline prepared by Road and Traffic Authority in Australia, in construction monitoring program should be linked to other contract documents and pre-construction monitoring should be undertaken during the environmental impact assessment (EIA) phase of the project to minimise the water issues and enhance water conservation efficiently. In addition, planning and management schedules for on- site activities and organisational policies impact on enhance the sustainable water practices.
Economical drivers	Howard (2003) explains that economic value of water based on a society's willingness to pay for it. Joyce (2012) argues that, the true value of water is still not reflected in all water related decision-making due to the existence of various socially constructed barriers. It is widely documented that requirement of changes to the water tariff system that is effective pricing system to free from water dilemma and impress the value and minimise wastage and misuse of water (Savenjije and Van der Zaag, 2002; Goodrum, 2008; IMWI, 2010; UN- Water, 2012; Horn, 2012). Water quantity, cost of water and water pricing are sub-economical drivers to be considered further.
Environmental drivers	Ofori (1992) recognises many of the site activities are potential source of water pollution. On the other hand, water is used in managing environmental pollution on construction sites as well. As Robert *et al*., (2006) say, over allocation and over use of river systems provide significant pressure. As Horn (2012) states quantification of water to sustain the environment is needed though it is difficult and a challengeable task. Holmes and Hudson (2000), Cole *et al*. (2005) and Pahwa (2007) identified that necessity of conditions for protecting natural resources and environmental impact due to construction. As Byrne (2011) explains, in water consumption 'fit for purpose" approach should be adopted that using potable water for all the purposes. Availability of water resource, sustainable water use, government regulations, and organisational policies identified as sub- environmental drivers.
Social drivers	The Workplace Health and Safety Queensland (2007) stated, as long as workplace health and safety is safeguarded, preservation of drinking supplies is the next most important priority in a construction site. In simply, quality of water for the workers as well as for the construction activities is critically impact on the project performance. Moreover, recent literature has shown that value of increasing public awareness towards water and environment (Eroksuz and Rahman, 2010). US Environmental protection agency (2012) divided water efficiency practices into two categories as engineering practices and behavioral practices. Thus, mainly quality of water, safety, behavior and attitudes are identified as sub-drivers in the social category.

A commitment to sustainable use of water through appropriate policies and investments, and conducting research and developments will lead to a more water secured world .The main survey broadly will consider the impact of each driver by identifying its sub-drivers and responsible parties in order to come up with appropriate actions and approaches to enhance sustainable water practices during the construction. In addition, the results will intend to identify the responsibilities according to the project level and the national level further. Section 6 elaborates the input of secondary data findings to formulate the research aim and the way forward of the study.

6. CONCLUSIONS AND THE WAY FORWARD

Although, water as the world's one of the most valuable assets, it is widely documented that water will be a challengeable resource faced by the world in near future if not taken proper actions towards water conservation and water efficiency to keep it as a sustainable resource. Water resource management puts effort on optimising the use of water and minimising the environmental impact of water use on the natural environment. Reviewing the extensive published literature, it was able to identify the research knowledge in terms of water resource management in the construction industry. Many studies hitherto have highlighted the importance of water quantity and quality that impact on the project performance and requirement of a better sustainability assessment for water handling during the construction. In addition, previous studies discussed some strategies such as water hierarchy, water audit and action plans to minimise wastage and misuse of water during the construction to enhance sustainable practices. Further, many researchers highlighted the importance of wastewater discharge methods from sites whereas unsustainable practises lead water pollution, and damage the environment. Like many other sectors, it was proved that existing requirement of sustainable practices in terms of water as a natural resource during the construction. Hence, reviewing the literature, the authors identified the following four drivers such as managerial drivers, economical drivers, environmental drivers, and social drivers in order to overcome existing issues and unsustainable practices. Organisational policies, project documents and planning and management were identified as some managerial drivers. It was identified cost of water, water pricing and water quantity are some economical drivers that enhance sustainable practices. Consequently, availability of water resource, government regulation and sustainable water use are considered under the environmental drivers. Quality of water, safety, user behaviour and attitudes are some social drivers that impact on proper use of water during the construction. Moreover, the authors believe that there is a strong link between each driver to uphold sustainable water practices during the construction.

Currently water stress is at marginal level in Sri Lanka. It was proved water is a scarce resource (Wijesiri, 2004). Similar to many other countries, Non-Revenue Water (NRW), wastage of treated water, absent of proper systems for cost recovery and ground water contamination are some critical issues in the Sri Lankan water sector too (Gamini and Werellagama, 2013; Menikdiwela, 2013). This paper was able to provide evidence to say even though resource optimisation is one of the main objectives under the sustainable construction, less attention has been paid on water resource in terms of sustainable practices. Strategic forum for construction group endorsed that to reduce water usage on construction sites it is important to have a clear understanding of where water is used, how much is used, where water is being wanted, and what behaviours and / or technology can be introduced to successfully reduce water wastage during the construction. There is no firm evidence of extensive research on water reduction techniques in Sri Lanka in order to uphold sustainable use of water during the construction. Thus, how water is used at a construction site from the beginning to end of a project in sustainable way is essential but still poor approaches could be seen in Sri Lanka as much as in many other developing countries. This paper looks at theoretical aspects in order to produce a conceptual framework as the next step of the study which can be used to develop best practice guidelines to uphold the sustainable use of water during the physical construction of building projects life cycle.

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A LITERATURE REVIEW ON MARKETING GREEN BUILDINGS: USE OF 4C MARKETING MIX APPROACH

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ABSTRACT

Green buildings is a concept, which is widely discussed in the present scenario. With the depletion of resources, spiralling up of energy costs, and the higher contribution of buildings to this unstoppable phenomenon, topic of green buildings is often heard in many construction platforms. However, in the real world context, green buildings are considered as a luxury and likewise there are many rooted myths which hinders the practical implementation of these greener buildings to a considerable extent. In such a situation, marketing is essential and should be carried out in such a way to promote and eradicate the misunderstandings of green buildings.

In general context, marketing green buildings refers to marketing the one off buildings which envisage the environmentally friendly concepts. Based on the marketing mix in order to market these buildings it is necessary to focus on the customer, his needs, cost and benefits communicating the value and focusing on the convenience.

Therefore, this research initially identifies the emergence of green buildings, its present context and concepts of green marketing. Then, it is followed by a brief identification of marketing mixes, whereas 4C marketing mix is identified to analyse the present context of marketing of green buildings.

Finally, it is concluded that key success is based on the customer satisfaction, which is applicable to three segments of clients namely the developer, owner and tenant. However, it was concluded that communication of facts and figures relating to the green guildings must be improved and so does the convenience in buying.

Keywords: *Green Building; Green Marketing; Marketing Mix.*

1. INTRODUCTION

Within the past couple of decades, the world has changed with an ever-increasing recognition that the mankind can no longer continue to use natural resources without facing environmental consequences (Warren, 2010). Therefore, it became a common goal to find ways and means to preserve the natural resources and fulfil the human needs hand in hand. In 1987, Brundtland Commission identified this as "Sustainability" and was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Further, in the perspective of construction, buildings have a profound impact on the environment and thus, even small changes in their sustainability can create major reductions in the current ecological footprint of the whole society (Eichholtz *et al.*, 2010). Hence, it is inevitable to focus on building construction within a sustainable framework.

In the vast area of "Sustainability", the concept or the subsector of "Green" is given a higher consideration. Sustainability criteria could theoretically be developed through a triple-bottom-line interpretation of sustainability (Pope *et al.*, 2004). In triple bottom line interpretation Social, Environmental and Economical

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subsectors are considered. When considering the 'Environmental" subsector in isolation, the green concept comes in to light.

Although no consumer product has a zero impact on the environment, the term green product is used to describe those that attempt to safeguard or improve the natural environment by preserving energy and/or resources and reducing or eradicating use of toxic agents, pollution, and waste (Ottman, 2006). Similarly, "Green building" is a term used to describe a building that is more energy and resource efficient, releases less pollution into the air, soil and water, and is healthier for occupants than standard buildings (Richardsones and Lynes, 2007). Therefore, it is essential to note that the Green Buildings (GBs) derive many benefits to its stakeholders and the society as a whole compared to conventional buildings.

However, it is a simple fact that these benefits of GBs must be communicated to the society. This proactive strategy of communicating nature friendly products or services can be identified through green marketing, thus making it extremely important for further discussion (Aggani, 2012).

2. GREEN MARKETING

The roots of green marketing run in to 1970s, where the wave of environmental concern gave rise to the 'ecological marketing 'concept (Hennison and Kinnear, 1976 cited Peattie and Charter, 2003). However, Peattie and Crane (2005) mentioned that in spite of some attention in the 1970s, it was really only in the late 1980s that the concept of green marketing emerged. Since then, the concept of green marketing has passed through several pit falls and plateaus in its journey. Lee (2008) explained evolution of green marketing in three stages as follows;

- First Stage: late 1980s, concept of "green marketing" was newly introduced and discussed in industry
- Second Stage:1990s, marketers started to experience a backlash as consumer concern for the environment and their desire for green products did not translate into purchasing behaviour
- Third Stage: Since 2000, with the implementation of more advanced technology, stricter state enforcement on deceptive claims, government regulations and incentives as well as closer scrutiny from various environmental organisations and the media, many green products have greatly improved and regained consumer confidence

Hence, it is obvious that Green marketing has now reached a good platform by its third stage. Reasons for this could be various. According to Ottman (2008), strong commitment to green would result in significant opportunities to grow a firm's business and to innovate and build brand equity. On the other hand, Polonsky, (1994) identified the general reasons for firms to increased use of Green Marketing as follows:

- Organisations recognise environmental marketing to be an opportunity that can be used to achieve its objectives
- Organisations moral obligation to be more socially responsible
- Governmental regulations forcing firms to become more responsible
- Competitors' environmental activities force firms to modify their environmental marketing activities and
- Cost factors associated with waste disposal, or reductions in material usage forces firms to adjust their behaviour accordingly

The American Marketing Association (AMA) who held the first workshop on "Ecological Marketing" in 1975 explained that "Green or Environmental Marketing consists of all activities designed to generate and facilitate any exchanges intended to satisfy human needs or wants, such that the satisfaction of these needs and wants occurs, with minimal detrimental impact on the natural environment" (Anand and Vasudevan, 2012). Further, Peattie and Charter (2003) defined green marketing as a holistic management process responsible for identifying, anticipating and satisfying the needs of customers and society, in a profitable and sustainable way. However, in general, "marketing" is defined as the management process responsible for identifying, anticipating and satisfying customer requirements profitably. It can be further illustrated in simple terms that the aim of green marketing is to create awareness among the consumers about the environmental issues and help them understand in what ways they can contribute to the helping of the environment (Jacob 2012, cited in Bartilsson and Christodolouo, 2013). Therefore in a nutshell it can be summarised that green marketing is simply a management process which is put in place to satisfy consumer needs and wants by striking a balance between profitability and minimising detrimental effects to the environment.

Successful green marketing shall focus on both customer satisfaction as well as improved environmental quality (Environmental leader, 2007). Further, it is emphasised that misjudging one of these aspects or overemphasising the later might lead to a phenomenon called "green marketing myopia| whereas if the improved quality of the environment is the main subject used in marketing messages, there is a high risk of failure for green products to reach out to the consumers (Environmental leader, 2007). Further, Ottman *et al.* (2006) emphasise that due to the misjudgments made in green marketing, consumers tend to satisfy from non-greener products. Hence it is crystal clear that when taking decisions on green marketing, it is necessary to follow certain tools, which are in marketing terminology known as "marketing mixes". This would provide a solid basis to take decisions in marketing as well as strike a balance between two extreme ends. Therefore, this research aims to develop a marketing mix for GBs based on literature.

3. GLOBAL ENVIRONMENTAL MOVEMENT AND GREEN BUILDINGS

Near the end of the 20th century, the construction industry became a centre of focus within the environmental movement (Hoffman and Henn, 2008). Building sector is one major component of the construction industry and it is considered as a sector which is highly responsible for increased energy consumption, solid waste generation, global greenhouse gas emissions, environmental damage, and resource depletion (CICA, 2002; Fuerst and McAllister, 2011). According to Rodman and Lenssen, 1996 cited Chan and Henn, 2008, buildings have a substantial influence on the environment as it accounts for one-sixth of the world's freshwater consumption, one-quarter of its wood harvest and two-fifths of its material and energy flows. This effect has become a global scenario and could be seen all over the globe irrespective of regions.

Buildings in the United States are responsible for 39% of U.S. primary energy use (includes fuel input for production), 39% of CO_2 emissions, 70% of electricity consumption, 12.2% portable water consumption and annual generation of 136 million tons of building-related construction and demolition (US Green Building Council, 2008). In Canada, buildings contribute to 35% of greenhouse gases, and they represent 33% of Canada's energy production, 50% of natural resources extracted, and 25% of waste going to landfill (Persram *et al.*, 2007). On the other hand being Asian cities, in Hong Kong, buildings consume overall half of all energy and about 89% of electricity, mainly and substantially for air-conditioning which is the cause of roughly 17% of Hong Kong's all greenhouse gas emissions (CE, 2008; EB, 2008 cited Chan and Henn, 2008). In Tokyo, building sector attributes to 73% of its emissions (Green building city marketing release, 2014). Having focusing on these figures, it is necessary to depict that buildings should be tailor-made in a way which would have a minimum negative impact on the environment and the society at large. Hence, Chan and Henn, (2008) argued that when these environmental impacts of building activities become more apparent, ''Green Building (GB)'' concept gained momentum in the construction industry.

4. GREEN BUILDINGS

Green, or sustainable building, is the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition (US Green Building Council, 2007). Pedini and Ashuri (2010) mentioned that GB is not a matter of choice or luxury but an essential for the environmentally concerned industry professionals, owners, developers, government officials and the rest of the society. It was further argued that though over the years green building principles became standards for many corporations, institutions, and government bodies as an indication of their ethical responsibility, the majority is still not up to the trend (Pedini and Ashuri, 2010). However, McGraw Hill Construction (2013) emphasised that GB is now growing across the globe despite particular region, economic condition or culture.

In the other hand, existing buildings which outnumber the new buildings are another concern within green construction. If all of new construction were to be ''green,'' and if no renovation took place, it would thus take several decades to improve the energy efficiency and sustainability performance of the existing building stock (Kok *et al*., 2012). Hence, green retrofit can also be considered another important aspect of this green building concept.

With reference to the discussion so far, the reason for moving towards to green buildings is mainly due to concern for preserving nature and its depleted resources. However, even though that is the main reason there are many benefits which can be derived by moving towards GBs which would lead to customer satisfaction as well. Many researches have looked into these benefits in different angles and in 2010, Pedini and Ashuri (2010) in their study in GBs summarised these benefits. These benefits can be mainly identified in five different categories which are namely; environmental benefits, market benefits, financial benefits, industry benefits and health and community benefits (Refer Figure 1).

In Green, performance of products are considered in both before purchase and after use perspectives (Peattie and Charter, 2003) and it is arguable that GBs should be analysed in the same way. With reference to Figure 1, many of these benefits are gained after the product is purchased, such as reduction in operating costs, improved air quality, improved productivity and so on. These benefits are derived after occupying or in marketing terms after "purchasing" the building while some benefits such as company recognition, increased job opportunities in the industry, use of intensives are achievable during or before construction. Hence, the customer will gain its satisfaction while using the product whereas the GB.

Even though there is a plethora of benefits of green buildings, the real question is whether these are known by the general public. Yudelson (2007) argued that engineers believe good results simply market themselves. As a result it has become a common understanding that if a green building performs well, that would speaks for itself, for the investors or other engineers to go for green buildings in future. In reality, this is hardly the case, as if achievements are not efficiently brought into the public knowledge, they may be forgotten and become insignificant (Yudelson, 2007). Therefore, it is apparent that green buildings must be marketed in the society as it is necessary for fruitful results. Further, as discussed, the satisfaction of using the GB is derived overtime and not as soon as the GB is purchased.

The benefits of green buildings must be communicated to the public through green marketing and eradicate the myths with concrete supportive arguments and information as if not, it may lead to suspicion of possible lack of green building construction (Eerikinen and Sarasooja, 2013). Hence, it is necessary to look into the green building market in the construction industry to get an overview of the present situation.

<table>
<tr>
<td colspan="2">Financial Benefits
• Reduce operating costs
• Reduce life cycle energy costs
• Enhance asses value and profit
• Improve employee productivity and satisfaction
• Optimise life cycle economic performance
• Lower absenteeism / Increased productivity
• Lower health related costs such as insurance premiums
• Lower litigation risks because of improved indoor air quality
• Staying ahead of regulations
• Lower employee turnover
• Longer economic life of the facility
• Tax abatements at the federal, state and local level
• Federal grants used as enticements to promote green building.</td>
<td colspan="2">Market Benefits
• Create value within the compatible market
• Higher occupancy rates
• Less vacancy period
• Meet growing demands by tenants
• Company recognition
• Lower advertising costs</td>
<td colspan="2">Industry Benefits
• Positive impact on the Construction Industry, (integrated, non-traditional processes, new materials)
• Allow technology to become part of the green building process improving the outcome of projects
• Allow professionals to become more qualified, educated, integrated
• Allow opening other countries and selling green building know-how
• Help other industries to benefit from new opportunities
• Help to increase job opportunities
• Eligible for grant money</td>
</tr>
<tr>
<td colspan="6" align="center">Benefits of Green Buildings</td>
</tr>
<tr>
<td colspan="3">Environmental Benefits
• Enhance and protect eco-system and biodiversity
• Improve water and air quality
• Reduce solid waste
• Conserve natural resources</td>
<td colspan="3">Health and Community Benefits
• Improve air, thermal, daylight and acoustic environments
• Enhance occupant comfort and health
• Minimise strain on local infrastructure
• Contribute the overall quality of life
• Set example in the community</td>
</tr>
</table>

Figure 1: Benefits of Green Buildings
Adapted from: Pedini and Ashuri (2010)

5. CURRENT SCENARIO OF GREEN BUILDING MARKET

As investors and occupants become more conversant with the environmental and social effects of the built environment, buildings with better sustainability credentials enjoy increased marketability (World Green Building Council, 2013). Yet, Chan and Henn, (2008) supported the fact that GB development still faces challenges in its market penetration as comparably higher initial costs and extra risks associated with GBs still act as barriers to the stakeholders from voluntarily entering into the new market. Nevertheless, Kats (2003) argued that the cost to build green will decline over time as the firms gain more experience designing and building environmentally sustainable structures.

However, according to MCgraw hill construction (2013), Green building market has shifted from 'push' to 'pull' and GB is increasingly seen as a business opportunity. This movement might be due to the fact that change in cost of buildings and the alarming savings of energy and resources with all other perceived benefits as evident from Table 1.

Table 1: Costs and Savings of GBs

Costs / Savings	**World Green Building Council (2013)**	**McGraw Hill Construction (2013)**	**Wiley *et al.* (2008)**	**Kats (2003)**
Design and construction cost increases	0.4% to 12.5% (new green building) 0.3% to 40.0% (green retrofit)	-	-	3.00 to -5.00/ft^2
Operating cost reductions		15% (new green building) 13% (green retrofit)	-	\$8.50/ft^2
Sales price / Asset value increases	0 % – 30%	7% (new green building) 5% (green retrofit)	\$30-\$137/ft^2	
Rental increases	0% – 17.3%	-	7.3%-17.3%	
Occupancy rate increases	0 %– 23.1%	-	10%-18%	
Energy saving	25% - 30% (new green building) 3%-17% (green retrofit)	-	40%	\$5.80/ft^2
Water saving	39%	-	-	\$0.50/ft^2

Besides financial benefits, Productivity enhancement and health benefits are other major concerns of GBs. As per the report of World green building council (2013), there is a 10%-25% of increase in mental function and memory, reduction of 8.5% of hospital stays, 20% - 26% of faster learning, increased productivity up to 18%, and increased retail sales up to 15% -40% is recorded from the employees working within a GB. Kats (2003) emphasised that due to more natural light and better air quality, GBs typically contribute to improved employee and student health, comfort, and productivity with data supporting that improved ventilation, temperature and lighting each provide measured benefits from 0.5% up to 34%, with average measured workforce productivity gains of 7.1% with lighting control, 1.8% with ventilation control, and 1.2% with thermal control. Thus, company's single most strategic Human Resource investment is likely to be the selection of green leased space as it results in two major benefits which are enhanced occupant productivity, and employee attraction and retention (Persram *et al.*, 2007).

According to Wiley *et al.*, 2008, green-labeled office buildings rent at a premium and achieve higher occupancy, relative to their competitors and further, with associated savings in operating expenses, GBs demonstrate superior income potential in the rental market. At the same time, Table 1 proves that cost premiums associated with GBs could be recovered with its perceived financial benefits over the life time. Hence, many professionals have come to a common understanding that increase in initial cost outweighs the perceived benefits and also the increment in cost for a green certified building would be around 5% compared to a common standard type of a building (Masry, 2012) which is acceptable. Hence, it is evident that initial cost which was the main focus of GB construction in past is now turning in to a concept of value considering the life cycle benefits.

Green Building Council (2013) established that studies around the world show a pattern of green buildings being able to attract tenants' attention and to command higher rents and sale prices and in markets and moreover, there are indications of emerging 'brown discounts' where buildings that are not green may rent or sell for less. Today, due to these environmental and strategic benefits many professionals are concerned about sustainable construction technologies. McGraw Hill Construction (2013) supported this fact highlighting their study which concluded 51% of architects, engineers, contractors, owners and consultants participated in the study anticipated that more than 60% of their work will be green by 2015. With all these derived benefits and proven facts with figures, still approximately 50% of professionals are having second thoughts on "going green" (McGraw Hill, 2013). This is quite alarming fact and it can be concluded that the successful green building projects all over the world has not still speak for themselves for the engineers and architects to move towards Green Buildings without having "second thought". Hence GBs are still to be marketed to a certain extent in the Green market and therefore, new ways and tools should be developed aiming enhancing the GB market. Further, in decision making it is a must to strike a balance to avoid situations like marketing myopia. Therefore, analysis of marketing mixes is essential.

6. MARKETING GREEN BUILDINGS

Marketers use numerous tools to elicit the desired responses from their target markets (Kotler, 2000). Therefore, in persuading the stakeholders of construction industry to move directly towards GBs, a tool kit should be developed. Marketing mix is the set of marketing tools that the firm uses to pursue its marketing objectives in the target market (Kotler, 2000). Hence, this tool kit can be used to market the GBs to the respective customers.

McCarthy (1960) offered the "marketing mix", as a means of translating marketing planning into practice (Bennett, 1997). According to Goi (2009), marketing mix is not a scientific theory, but merely a conceptual framework that identifies the principle decision making managers make in configuring their offerings to suit consumers' needs.

The mostly discussed Marketing mix is 4Ps developed by McCarthy. It consists of four components, namely Product, Price, Place and Promotion. These four components can be illustrated as follows:

- Product – All factors relating to the actual product visible to the consumer
- Price – Listed price together with the factors associated with price such as discounts
- Place - All distribution points and locations from which the product is available to the customer
- Promotion – Efforts made by the company to publicise the product.

With reference to MaCarthy, it is essential to focus on these components when making decisions. However, this marketing mix was criticised by many researches, (Yudelson, 1999; Anderson and Taylor, 1995). Further, Anderson and Taylor (1995) illustrate that even though this marketing mix is applicable in the post second world war period, the applicability in the present is questionable. Brownlie and Saren (1992) argue that consumers' and society's requirements of business are now broader and are expected to tackle major sustainability challenges. Hence it is a marketing mix with customer perception is required.

McCarthy's 4Ps concept has been criticised as being a production-oriented definition of marketing, and not a customer-oriented (Popovic, 2006 cited Goi, 2009). Lauterborn (1990 cited Goi, 2009) claimed that each of these variables should also be seen from a consumer's perspective. Marketing mixes can be identified in product perspective as well as in customer perspective. As construction industry is a customer centric industry which produces tailor made, unique products the researchers are more specific in customer perspective in choosing a marketing mix for this study.

This transformation of McCarthy's 4Ps to customer perspective is accomplished by converting product into customer solution, price into cost to the customer, place into convenience, and promotion into communication, or the 4C's. The 4Cs model has a customer-centric focus and ensures the marketing mix from the customer's point of view. Hence, Next section analyses each component of 4C model in the context of green buildings.

7. MARKETING MIX IN GREEN BUILDINGS PERSPECTIVE

7.1. CLIENT/ CUSTOMER SOLUTION

The first C of the 4C model suggests that a product is required to cater the needs and wants of client. Further, recent researches indicate that over 60% of construction builders and re-modellers report that customers are willing to pay for green (McGraw Hill, 2012). Hence, it is evident that the customer focus is now towards the GBs. Further, when defining "customers" in buildings there are couple of clusters to focus onto which are namely; Owners, Developers and Tenants. The needs of these segments are different. The owners concern would be to increase the return on investment, reduce cost and depreciation. In contrast, the tenants would be more concerned towards the wellbeing of the users and operating cost. Developers are more concerned on higher values of building and lower costs and higher prices in the market. These segments and the respective needs and wants are therefore different although there may be certain similar requirements be present (Refer Figure 2).

Knowing the customer and their needs are the key to success in Green Marketing (Ottman, 2008; Aggrawal and Satnam, 2014). Hence, in marketing GBs, identifying the customer needs and satisfying these needs would be one of the requirements. Green marketers can attract customers on the basis of performance, money savings, health and convenience, or just plain environmental friendliness, so as to target a wide range of green consumers (Indoria, 2012).

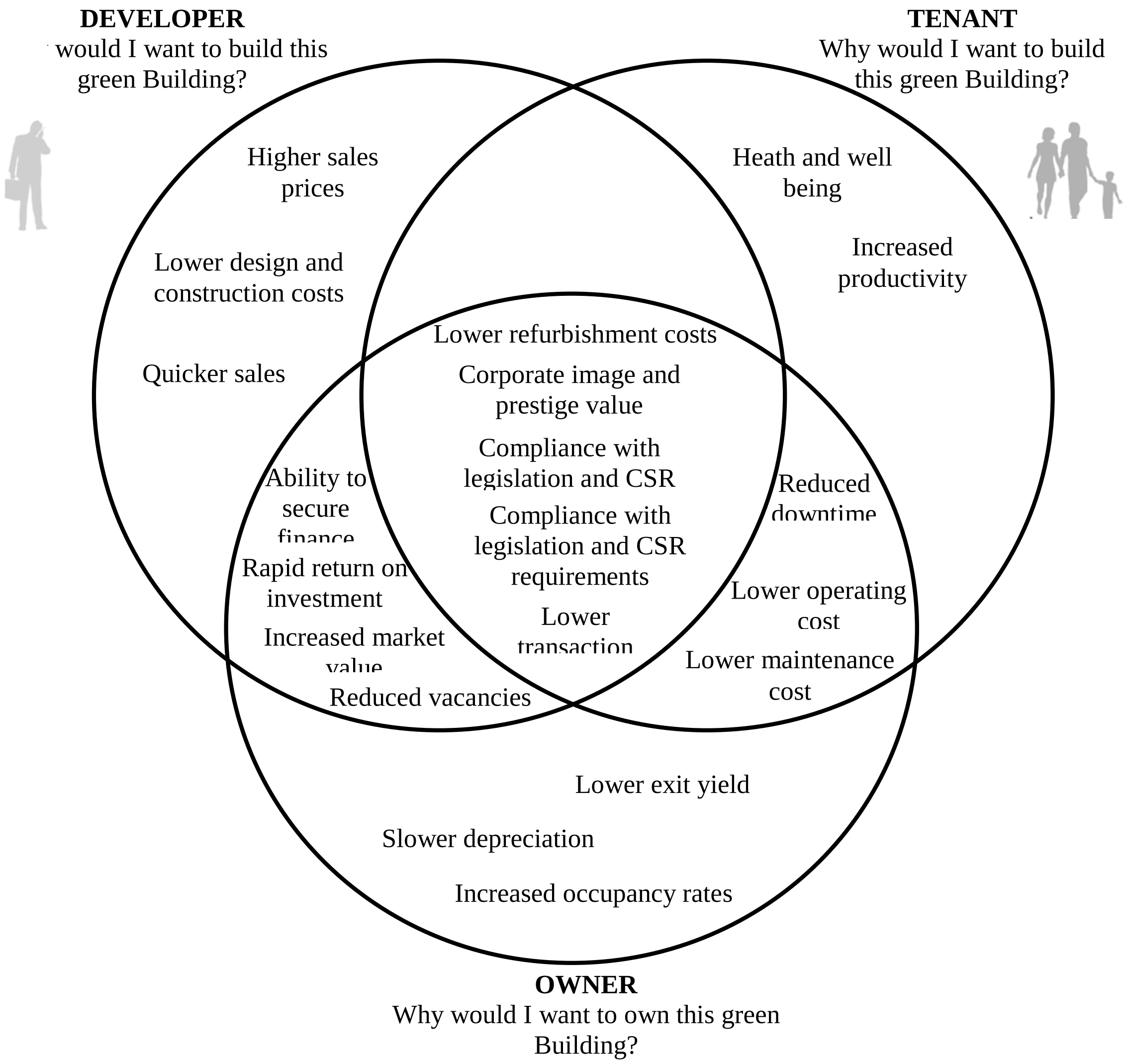

Figure 2: Interests of Clients
Source: World Green Building Council (2013)

7.2. *COST*

The cost in four C's marketing mix relates to all the costs incurred in satisfying the clients. Hence, from the initial stage of the construction to costs incurred throughout the life cycle is concerned in this component of 4C model.

As far as the initial cost is considered, the increasing affordability of green commercial real estate is not well understood by many real estate professional (Tobias, 2011). The main myth involved in costs is that 76% (McGraw Hill, 2012) believed that the initial costs higher which acts like as a huge barrier in green building development. It is evident that extra costs will gradually be reduced when the new practices and technologies are developed and accepted by the market (Chan and Henn, 2008)

When referring to Table 1, it is crystal clear that the overall cost is reduced due to green buildings as far as the life cycle of the building is concerned. The operating cost and the maintenance costs are reduced by 15% in new green buildings and 13% in green retrofits (Refer Table 1). Further, reduction in energy usage which is greater than 25%, water consumption reduction 39%, illustrates a higher reduction in life cycle cost (Refer Table 1).

As opposed to standard buildings, green buildings derive many health and productivity benefits. Substantial increase in mental functioning, productivity due to improvements in the system, increase in worker productivity and retail sales are the other illustrated cost incentives (Section 4).

Apart from the quantified data there are many benefits perceived by green buildings. The literature provides the benefits as environmental, market, financial, industry and health and community benefits. (Refer Figure 1). Therefore, in developing a marketing mix, the perceived cost as in the whole process of procuring a green building together with its life cycle can be reduced.

Hence, in applying the marketing mix, 4C model to green Buildings, it is necessary to focus on the initial cost and the operating cost as well. Thus, a whole life cost approach should be adopted. In most of the cases, developers and owners will focus on the lower initial cost, whereas tenants will consider the initial cost as well as the operating cost of the building. As a result in green marketing, when developing a marketing mix, both these aspects must be highlighted to respective clients.

7.3. COMMUNICATION

All interactions between clients are considered as communication in 4C model. The communication is mostly carried out through professional bodies established in many countries such as Green Building Council of Sri Lanka, United States Green Building Council, Australian Green Building Council and so on. These professional bodies carry out many activities and strategies to promote and communicate the benefits and the needs of going green in buildings. Further, these bodies have come up with different green rating systems such as LEED, BREEAM, so that it is possible to provide recognition to green buildings which have a less impact to environment and further, they suggest ways to promote green buildings.

For example, in a tool kit developed by Green Building Council of Australia (2013), certain activities and opportunities are identified to communicate and promote the greener projects, which are generalised and identified as follows;

- Use of certified logos
- Building the profile and awareness of the green building by developing project case studies with the collaboration of the respective green professional bodies
- Issuing media releases
- Improving awareness of the certification through respective websites

Consumer awareness on green buildings products can further be created by spreading the message among consumers about the benefits of environment friendly products which would be through posting of profiles related to green marketing on social networks creating awareness within and across online peer groups (Indoria, 2012).These can be identified as the mostly used methods of communicating to the client on GBs. However, irrespective of these possible communication methods, it is still questionable whether the essence of GBs are communicated to the clients.

Saha and Darnton (2005) argued that that Green marketing has not lived up to the hopes and dreams of many managers and activists. This is somewhat applicable in GBs as well because even though there is an established platform for green marketing the real essence of GBs has not yet reached the customer. Hence, it can be emphasised that benefits from GBs are only vaguely understood and not widely penetrated particularly in the private sector of building industry (Chan and Henn, 2008).

Further in the study by Saha and Darton (2005), most of green marketing suffered from failure as most of its arguments were not put into practice. The main reason may be the miscommunication in the perspective GBs. A study by Akter (2012), specifically identify that majority is unaware of these greener products, its benefits and use, which also applicable to GBs as well to a certain extent. Hence, considering these facts, when developing the marketing mix, this would be considered as the lacking point in GBs.

7.4. CONVENIENCE

Since the marketing mix is developed based on products of standardised nature this is defined as “how and where the product can be purchased”. In the perspective of construction, buildings are considered to be products. These products are one off and unique products based on one location. As a result, purchasing a building is a project and it commences from the initial design to post development stage of the building. Within that period "convenience" refers to many aspects not just simply how and where it should be purchased.

Irrespective of place of purchasing, the initial cost of a building is ultimately higher compared to any other product. Hence, in the perspective of buildings, financing options in procuring should be convenient for the product or the building to be bought by the client.

Through the study by Tobias (2011) for the US green building finance review, many potential convenient options are identified. These can be illustrated as follows;

- Implement government regulations for leasing preferences for green properties
- Provide incentives for the development and retrofitting of green and energy-efficient buildings.
- The regulation of lending institutions to encourage green and energy efficient lending.
- Use government regulations and tax incentives to encourage investment in green real estate.
- Allowing accelerated depreciation for green property owners in tax calculations

In the study by Ottman *et al*. (2006), emphasise that in order make green marketing successful, the product should be environmentally friendly and there should be customer satisfaction. However, to gain customer satisfaction there should be a value for money for the customer. Hence, in order to make GBs more marketable in the industry it is necessary to make further practical financing options especially focusing on GBs.

8. CONCLUSIONS

Rise of environmental concern resulted in emergence of greener products ranging from day today commodities to automobiles and buildings. Construction being a larger consumer of earth's natural resources became a focus of attention as greening construction would lead to larger reductions in effects to the environment. Thus, green buildings became a globally popular concept. GBs not only focus on constructing new buildings, but also retrofitting the larger number of existing buildings.

GB market is no more a new concept. It has been established and passed through many stages of its life and yet evolving to reach its maturity. Marketing GBs is different from marketing an off the shelf product. Buildings are unique in its nature, incur large capital and custom made to clients' needs at a particular location instead of mass production at a manufacturing factory. Hence, reasons for building a GB and retrofitting an existing building to a green should demonstrate and convince to clients and this could be considered as the major concern in GB marketing. Hence, this study attempted to find out the factors considered in developing a marketing mix to a GB.

Marketing literature identifies numerous marketing mixes as marketing tools that a firm uses to pursue its marketing objectives in the target market and these were defined mainly from product oriented or customer oriented perspectives. Construction being a customer driven industry, 4C model of marketing was identified as a tool kit to analyse the scenario of green building marketing. 4C model identifies 4 elements as client/customer solution, cost, communication and convenience.

Client is identified as the key factor in marketing GBs. Further, there are three segments of clients namely the developer, owner and the tenant. Each of these clients have different needs and these must be fulfilled in order to market the GBs. The key to success is identifying the needs of customer. Further, customers can be attracted through emphasising the performance of the building.

Cost of the GB is the next component and it is vaguely understood very often. The life cycle cost of the GB is comparably lower than a standard building and the benefits gained by the client add more value to the building itself. However, it is questionable as to whether this is conveyed to the general public. Communication being the third component in marketing mix model this information should be transferred to the community using different media and techniques such as using logos, social media, awareness certificates and so on. As building are unique projects, convenience of buying refers mainly to financing the purchase. This is applicable to any type of client. However, there is a lack of available financing options put into practice specifically focusing on GBs which suggests that more attention is now needed in this regard.

9. LIMITATIONS AND FURTHER RESEARCH DIRECTIONS

This study is based on literature and therefore an empirical research of the study is needed. Further, it is necessary to focus on different sectors of buildings such as commercial buildings, recreational facilities and educational facilities as each of these building types will have different special marketing features. There are certain other marketing tools and this study further can be extended based on these tools as well.

Based on the conclusions, it is evident that further research on communication and convenience of marketing is required as there is a lack of research evidence in these segments.

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A RESEARCH PARADIGM FOR DEVELOPING A FIRE RISK ASSESSMENT MODEL FOR NEW CONSTRUCTION SITES IN HONG KONG

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ABSTRACT

In Hong Kong, the construction industry is regarded as high-risk. Amongst all types of construction accidents, however, industrial practitioners tend to give less attention to those related to construction site fires, that is, fires which occur during new construction. Fire is perceived as a significant but common risk associated with construction projects which can lead to serious damage. Although construction site fires may not be frequent, the consequences are usually severe. This paper will present an overall research framework for developing a fire risk assessment model for new construction sites in Hong Kong. The research process mainly involves the identification of key fire risk factors and their associated sub factors contributing to fire risk for a construction site, and the development of a fuzzy fire risk assessment model based on the identified fire risk factors. The research methods to be adopted include desktop literature review, Delphi survey technique, empirical questionnaire survey and fuzzy set theory. The model can be used as an objective tool for measuring and comparing the overall fire risk levels existing at different construction sites. Therefore, high-risk areas could be identified and improved. The research findings from the developed fire risk assessment model will ultimately lead to the provision of remedial measures to reduce fire risk at new construction sites. Although the research study will primarily focus on the prevailing situation in Hong Kong, the research methodology will be applicable to many other parts of the world for facilitating international comparisons.

Keywords: *Assessment Model; Construction Site; Fire Risk; Hong Kong; Research Framework.*

1. INTRODUCTION

In Hong Kong, the construction industry is regarded as high-risk. It is evident that the construction industry still records the highest accident rate and number of fatalities amongst the various major industry sectors throughout the world (Choudhry *et al*., 2008; Labour Department, 2013). Amongst all types of construction accidents, however, industrial practitioners tend to give less attention to those related to construction site fires, that is, fires which occur during new construction.

Fire is perceived as a significant but common risk associated with construction projects which can lead to serious damage. Although construction site fires may not be frequent, the consequences are usually severe. Statistics from the Labour Department (2013) indicate that a construction site fire will not only delay the completion date of the project but can also result in serious monetary losses and even injuries and fatalities.

There are several reasons for the occurrence of fires on site, one of which is a lack of awareness of the nature of various fire risks and the other is a lack of a proper fire risk assessment mechanism (Yam *et al*., 2009). Fire risk assessment ought to be routine as a proactive and formal procedure in fire prevention. It should offer a structured and systematic assessment of fire safety management capabilities, fire protection capabilities, fire risks on site and emergency handling capabilities during a fire (Lo, 1999). It should also

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provide practical solutions and effective recommendations for fire risk mitigation. In fact, there exists a strong urgent need for an appropriate fire risk assessment mechanism for building construction sites.

In order to develop the fire risk assessment model for construction sites, it is essential to systematically examine the essential fire risk factors and their associated subfactors which affect both the likelihood of a fire arising and/or its level of severity to a construction project in terms of damage, life, time or cost if a fire does occur. Therefore, the proposed research study aims to develop a holistic fire risk assessment model for new construction sites in Hong Kong using the Delphi survey technique, empirical questionnaire survey and fuzzy set theory. It will be a multi-factor model where the essential fire risk factors are expressed both in broad terms and as finer, more detailed, subfactors. The model can be used as an objective tool for measuring and comparing the overall fire risk levels existing at different construction sites. Only new construction sites will be included in this investigation and not those building sites where substantial renovation with occupants inside is taking place. The developed model will be adjusted, validated and confirmed for use following face-to-face interviews with senior industrial practitioners and some real-life case studies.

2. BACKGROUND OF RESEARCH

In spite of Hong Kong government departments' efforts to mitigate fire risk through promulgating minimum fire safety requirements and measures (Yam *et al*., 2009), the situation of construction site fires has not been well improved as seen from the frequently reported cases of fires on construction site. In fact, serious construction site fires have occurred over recent years in Hong Kong. For example, there occurred a number 4 alarm fire at the site of the high-rise private residential building "One Silver Sea" in Tai Kok Tsui on 26 October 2005. Another number 4 alarm fire broke out on 1 December 2006 at the site of the Kowloon Bay Enterprise Square Phase V Mega Box Building, which is a private commercial development. About 2 weeks later, on 15 December 2006, two workers were seriously injured by a sudden gas explosion on a construction site in Shatin.

Fire occurrence always generates a risk on construction projects which may not only delay the completion date but also cause enormous financial losses and even causalities. There exist many causes of fire on construction sites, but key is the general lack of awareness of the nature of various fire risks. The undesirable situation of construction fires may be attributed to the lack of an appropriate fire risk assessment mechanism that could be employed to evaluate the potential fire risk levels. Therefore, the implementation of a proper fire risk assessment is regarded as good fire safety management practice for the prevention of fire. A structured and systematic assessment on site of fire safety management capabilities, fire protection capabilities, fire risks and emergency handling capabilities in fire can offer effective solutions and useful recommendations for mitigating the risk of a site fire (Lo, 1999). Systematic research is needed in order to understand how to build a model which will provide a single measure of fire risk on a particular site, a useful tool as part of a fire risk assessment system.

Several research studies have led to the development of effective fire risk assessment tools suitable for various scenarios and conditions (e.g. Marchant, 1982; Shields *et al*., 1986; Watts, 1997; Parks *et al*., 1998). A few recent studies have been undertaken, particularly in Hong Kong, to assist in the evaluation of fire safety levels of occupied premises. For instance, Chow *et al*. (1999) proposed a fire safety ranking system for dilapidated high-rise private buildings. Lo (1999) established a fire risk assessment system using the Delphi survey technique together with a fuzzy set theory approach to assess the overall fire risk levels in housing blocks. The assessment system allowed a prioritisation of various fire risk factors so that improvement works could be carried out at those areas with higher risks.

Chow and Liu (2001) generated a fire safety ranking system using a 20-point measurement scale. The study focused on karaoke entertainment establishments because of their box partition design and often crowded long corridors. Lo *et al*. (2001) introduced the reliability interval method to assess the fire risks for existing high-rise buildings. Lo *et al*. (2005) further adopted the reliability interval method and gray relational model for fire safety ranking of existing buildings. However, due to the fact that fires on construction sites are not as usually as life threatening as those within existing occupied premises, construction industry related fire safety/risk assessment systems have been developed for use in the latter context. There seem to be very few or even no assessment tools available for examining the fire risk levels on "new construction sites".

In view of the identified knowledge gap in fire risk assessment, the research team has carried out some preliminary groundwork to examine and assess fire risks on building construction sites in Hong Kong. An initial list of fire risk factors and subfactors were compiled and published in the study of Yam *et al*. (2009). Drawing upon previous studies on fire risk assessment tools and the list of fire risk factors and subfactors derived by the authors, the proposed study attempts to develop a fire risk assessment model for new construction sites.

3. RESEARCH AIMS AND OBJECTIVES

This research study aims to establish a comprehensive, objective, reliable, and practical fire risk assessment model for new construction sites in Hong Kong, and to identify any high-risk areas requiring remedial measures to reduce fire risk. An enhanced understanding of the key fire risk factors leads naturally to the study's another aim of generating an objective tool for measuring and comparing the overall fire risk levels at different construction sites in search of best practice recommendations for improvement. The following three research objectives were designed to achieve the aims of the proposed research study.

a) Objective 1: To identify a list of key fire risk factors and their associated subfactors which contribute to fire risk for a construction site.
b) Objective 2: To develop a fire risk assessment model for measuring and comparing the overall fire risk levels of different construction sites.
c) Objective 3: To provide the ability for users to identify high-risk areas where special attention is needed, and enable the provision of remedial measures to reduce fire risk.

4. RESEARCH METHODOLOGY

The overall research process of this study will comprise the following stages: (1) literature review; (2) face-to-face structured interviews; (3) a Delphi questionnaire survey; (4) an empirical questionnaire survey; (5) data collection; (6) data analysis; (7) development of a fire risk assessment model; and (8) validation of the developed model. The two questionnaire surveys will be different in nature. The Delphi method will be used for collecting and analysing the data collected from the Delphi questionnaire survey, while fuzzy set theory will be used for analysing the empirical questionnaire survey. The scope of the study is to be restricted only to new construction sites only in Hong Kong and therefore excludes existing buildings undergoing substantial renovation works with occupants inside. Figure 1 indicates the overall research framework for the proposed study for reference.

To achieve each of the three objectives as set before, corresponding research methods and process are designed as follows.

(a) Objective 1: To identify a list of key fire risk factors and their associated subfactors which contribute to fire risk for a construction site.

The study will begin with an extensive review of the literature on fire risk assessment systems both for existing buildings and new construction sites from all available sources. All previous relevant studies will be summarised so as to condense existing knowledge and experience about prevailing practices, building regulations and fire codes on fire risk assessment, together with previous major fire accidents. The review exercise will help develop the overall research framework and help prepare appropriate templates for the in-depth structured interviews, and the Delphi and empirical questionnaire surveys.

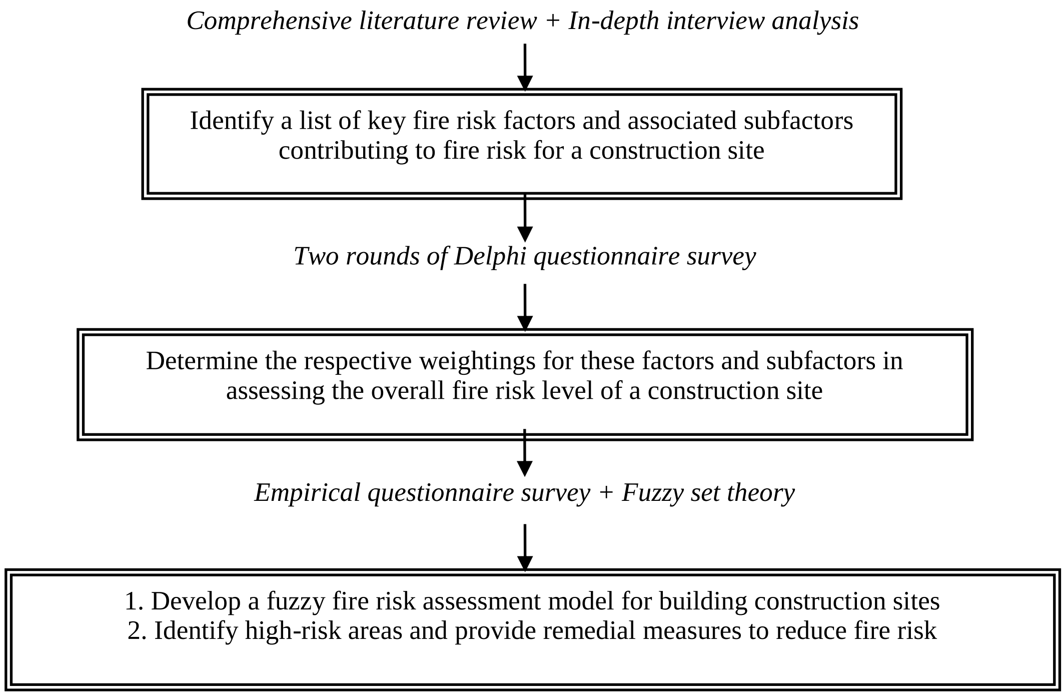

Figure 1: Flow of the Overall Research Framework

Typical core factors affecting the degree of fire risk may include: (1) Restrictions for on-site personnel; (2) Means of access for firefighting and rescue; (3) Means of escape in case of fire; (4) Storage of flammable liquids or dangerous goods; (5) Electricity management; (6) Fire services equipment and installation; (7) Attitude of main contractor towards fire safety; (8) Characteristics of construction site; (9) Safety procedures for evacuation on-site; (10) Site environment during fire; and (11) Safe behaviours of on-site staff (Yam *et al*., 2009). Each of these 11 fire risk factors will be further subdivided into some underlying subfactors which represent the detailed factors affecting that particular type of fire risk concerned, as outlined in Table 1. Through the literature review, an initial checklist of fire risk factors and their associated subfactors for a construction site will be placed within a systematic hierarchy of three levels: (1) the overall fire risk (at first level); (2) the fire risk factors (at second level); and (3) the fire risk subfactors (at third level) as portrayed in Figure 2. Then a series of face-to-face in-depth interviews with relevant senior industrial practitioners (e.g. government officers, project managers, safety managers, safety officers, fire safety engineers, etc) will be conducted to solicit their opinions and feedback on these key fire risk factors as captured from the literature based on their abundant hands-on experience with site fire safety. Finally, a full list of fire risk factors and subfactors will be produced.

After the literature review and interviews, two rounds of Delphi questionnaire survey will be launched as adopted by Lo (1999) in order to evaluate the relative importance (weightings) of the respective fire risk factors and subfactors. The Delphi method is a highly formalised method of communication that is designed to extract the maximum amount of unbiased information from a panel of experts (Chan *et al*., 2001; Yeung *et al*., 2007; Chan and Chan, 2012). It is generally conducted in several rounds interspersed with group opinions and information feedback in the form of relevant statistical data. The desired outcome is that, by using an iterative forecasting procedure, on reaching the final round, the experts will have achieved unanimity on the issues put before them (Manoliadis *et al*., 2006). The selected panel of Delphi experts will be either industrial practitioners equipped with extensive hands-on working experience in fire risk assessment or prominent academics with demonstrated research experience in fire safety. The Delphi experts will include government officers, safety managers, safety officers, fire safety managers, fire safety engineers, project managers, building engineers, building services engineers, academics and other allied construction professionals.

Table 1: List of Fire Risk Factors and their Associated Subfactors for a Construction Site

1	**Restrictions for On-site Personnel**
1.1	Enforcement of smoking prohibition
1.2	Gas welding and flame cutting work done by competent workers
1.3	Supervision by site supervisors or foremen
1.4	System of rewards and punishment
1.5	Use of hot work procedures
2	**Means of Access for Firefighting and Rescue**
2.1	Free from obstruction
2.2	Emergency vehicle access
2.3	Provision of firefighting and rescue staircases
3	**Means of Escape in Case of Fire**
3.1	Adequate emergency lighting
3.2	Adequate width of means of escape
3.3	Free from obstruction
3.4	Provision of exit signs
3.5	Under good condition
4	**Storage of Flammable Liquids or Dangerous Goods**
4.1	Clearance of rubbish
4.2	Flammable liquids in spraying area stored in metal container with self-closing lid
4.3	Flammable liquids stored in closed containers that are kept in cupboard or bin
4.4	Reasonable quantity of flammable liquids in spraying area
4.5	Removal or disposal of combustible materials after use
4.6	Smoking prohibition
4.7	Use of dangerous goods store
5	**Electricity Management**
5.1	Adequate electricity supply
5.2	Proper insulation and protection of electricity wiring
5.3	Use of earth leakage circuit breakers
6	**Fire Services Equipment and Installation**
6.1	Fire alarm
6.2	Fire blanket
6.3	Fire hydrant riser
6.4	Fixed fire pump with electricity supply
6.5	Hose reel
6.6	Periodical inspection
6.7	Portable fire extinguishers at each floor and site office
6.8	Portable fire extinguishers at open flame workplace
6.9	Provision in area of spraying flammable liquids
6.10	Under good condition
7	**Attitude of Main Contractor towards Fire Safety**
7.1	High level of commitment to fire safety system
7.2	High level of concerns over the probability of starting fire
7.3	Reasonable budget spent on construction site fire safety
8	**Characteristics of Construction Site**
8.1	Choice of less combustible materials
8.2	Good level of ventilation
8.3	Types of work that induce the number of fire sources (e.g. welding work, open flame)
9	**Safety Procedures for Evacuation On-site**
9.1	Designated staff (e.g. wardens) help with evacuation in fire situation
9.2	Evacuation training for on-site staff
9.3	Location of emergency signage
9.4	Planned evacuation route

10	**Site Environment during Fire**
10.1	Low hazard of smoke
10.2	Low hazard of irritant gases
10.3	Low hazard of toxic gases
11	**Safe Behaviours of On-site Staff**
11.1	Peer relationship of individuals
11.2	Willingness of on-site staff for evacuation in fire situation

Source: Yam *et al*. (2009)

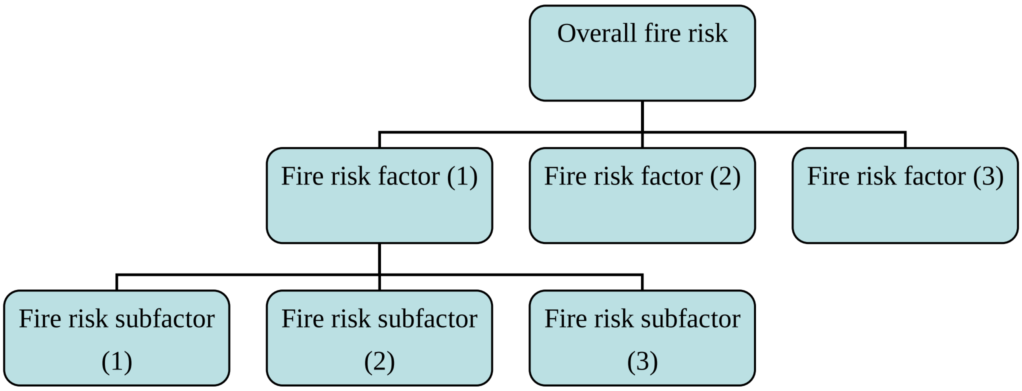

Figure 2: A Systematic Hierarchy of Fire Risk Factors and their Associated Subfactors for a Construction Site

The first round of the Delphi questionnaire survey will be based on the already identified list of various fire risk factors and subfactors. The target respondents will be invited to provide "importance" ratings to each of the fire risk factors and subfactors elicited based on a five-point Likert scale. A statistical analysis will be performed on all survey questionnaires received in which the mean ratings for all the fire risk factors and subfactors will be computed. Hence, a series of fire risk factors and subfactors with their respective weightings will be derived based on the mean ratings advocated by the Delphi group of panel experts. The weighting for each fire risk factor or subfactor will be calculated as their individual mean ratings divided by the total mean ratings of all the factors or subfactors under consideration as computed by using the following equation (Chow, 2005; Ng *et al*., 2005; Yeung *et al*., 2007; Eom and Paek, 2009; Chan *et al*., 2011; Chan and Chan, 2012):

$$W_{FRF_a/FRS_a} = \frac{M_{FRF_a/FRS_a}}{\sum_k M_{FRF_k/FRS_k}} \quad \text{for a = 1} \qquad \text{(Eq: 01)}$$

Where,

W_{FRF_a/FRS_a} represents the weighting of a particular fire risk factor (FRF)/fire risk subfactor (FRS)

M_{FRF_a/FRS_a} represents the mean ratings of a particular FRF/FRS

$\sum_g M_{FRF_k/FRS_k}$ represents the summation of mean ratings of all the FRF/FRS

In Round 2 of the Delphi questionnaire survey, the participating Delphi experts will be given the consolidated results obtained from Round 1. The average ratings of the Delphi experts for each fire risk factor and subfactor, together with the Delphi expert's own ratings suggested in Round 1 will be provided. The Delphi experts will then be requested to reconsider their ratings to see if they would like to adjust their original option in the light of the mean scores by all the Delphi experts. By doing so, the series of most important weighted fire risk factors and subfactors will be found out.

(b) Objective 2: To develop a fire risk assessment model for measuring and comparing the overall fire risk levels of different construction sites.

Having determined the respective weightings for those key fire risk factors and subfactors from the two rounds of Delphi questionnaire survey, an empirical questionnaire survey will be undertaken to develop a comprehensive, objective, reliable, and practical fire risk assessment model. Since many fire risk factors and their associated subfactors are descriptive (linguistic) and "fuzzy" in nature and only vague or imprecise information is often available for the assessment, the value judgments of assessors are essential during evaluation. Consequently, it is desirable to generate a multi-criteria evaluation model for fire risk assessment by adopting a fuzzy set theory approach (Watts, 1997). Fuzzy synthetic evaluation (FSE), which enables multi-criteria evaluation, can be applied to offer a synthetic evaluation of one object relative to another objective in a fuzzy decision environment with many factors or criteria (Hsu and Yang, 1997).

Fuzzy synthetic evaluation, building upon fuzzy set theory, has been used within many disciplines. Sadiq and Rodriguez (2004) also employed this method to determine the health risks inherent with disinfection by-products. Zhao *et al*. (1997) proposed a fuzzy integrative evaluation method for assessing the risk factors of any project in general. Hsu and Yang (1997) developed a fuzzy synthetic evaluation model for selecting the most suitable candidate in a recruitment process for university academic staff. Chan *et al*. (2011) generated a fuzzy risk assessment model for guaranteed maximum price and target cost contracts in the construction industry of Hong Kong. It can be observed from their research that fuzzy synthetic evaluation is good at dealing with complicated evaluations where multi-attributes at multi-levels are involved.

This proposed research study will follow a similar approach to fire risk assessment analysis by considering both the likelihood of occurrence and the level of severity to the construction site of various fire risk factors and subfactors based on the abundant hands-on experience of target survey respondents. The target respondents will include government officers, safety managers, safety officers, fire safety managers, fire safety engineers, project managers, building engineers, building services engineers and other allied construction professionals. They will be invited to rate both the likelihood of occurrence and the level of severity of each fire risk factor and subfactor on a five-point Likert scale (1 = very low; 2 = low; 3 = medium; 4 = high and 5 = very high). A score representing the average total overall fire risk level for all the construction sites as a whole based on the personal non-project-specific perceptions of the survey respondents will be computed using fuzzy set theory and may serve as a benchmark score for reference within the industry. The calculation of this overall score is based on the assessment for each weighted fire risk factor and subfactor identified. The assessed values of these fire risk factors and subfactors will be used to derive their corresponding fuzzy membership functions.

For each fire risk subfactor identified, the membership function can be found by the personal evaluation of the survey respondents. For example, if the survey results on the first fire risk subfactor "1.1 - Enforcement of smoking prohibition" indicated that 2% of the respondents opined the level of severity of this risk to the project as very low, 17% as low; 33% as medium; 30% as high and 18% as very high, then the membership function of this risk would be set as:

$$C1 = \frac{0.02}{\text{very low}} + \frac{0.17}{\text{low}} + \frac{0.33}{\text{medium}} + \frac{0.30}{\text{high}} + \frac{0.18}{\text{very high}}$$

$$C1 = \frac{0.02}{1} + \frac{0.17}{2} + \frac{0.33}{3} + \frac{0.30}{4} + \frac{0.18}{5}$$

The membership function can also be expressed as (0.02, 0.17, 0.33, 0.30, 0.18). Similarly, the membership functions of other fire risk subfactors and the corresponding fire risk factors for both severity and likelihood can be computed using the same method. The derived fuzzy membership functions together with the weightings obtained from the two rounds of Delphi questionnaire survey will enable the development of the fuzzy fire risk assessment model (Yam *et al*., 2009). The proposed fire risk assessment model could also be modified to suit places other than Hong Kong by altering as appropriate the set of fire risk factors and subfactors, adjusting the membership functions of the input variables, and changing the fuzzy inference rules.

(c) Objective 3: To provide the ability for users to identify high-risk areas where special attention is needed, and enable the provision of remedial measures to reduce fire risk.

After inputting the scores of the respective essential factors and associated subfactors included in the fire risk assessment model for a particular single project-specific construction site, any high-risk areas will be captured, and the opinions of various target survey respondents on appropriate risk mitigation measures to reduce fire risk will be solicited. By using a fuzzy set theory approach, various assessment scores will be found on each of the fire risk factors and subfactors for a particular construction site so that immediate improvement strategies and remedial measures can be prioritised according to the magnitude of the respective scores. If a certain fire risk factor or subfactor has a high score, then it should be given a higher priority for improvement works. The risk assessment scoring system serves as a decision support tool for the prioritisation of fire risk remedial measures.

5. VALIDATION OF RESEARCH FINDINGS

Triangulation from multiple sources will be employed to reinforce the credibility of the findings obtained from the research data and subsequent analyses. Results derived from the empirical questionnaire survey and in-depth interviews will be cross-referenced to the published literature as well as with each other whenever appropriate. Appropriate workshop discussions with prominent industrial practitioners who have acquired extensive hands-on experience in dealing with various fire risk factors on new construction sites will be organised to generate relevant information and to supplement and/or confirm the outcomes of the analyses, and a set of possible recommendations for improving the developed fire risk assessment model based in Hong Kong. A meeting will be scheduled via discussions and moderations to validate the research findings and explanations with practitioners involved in the study.

6. CONCLUSIONS AND SIGNIFICANCE OF RESEARCH

The prospective results of the proposed research study are mainly three folds: (1) Deriving a list of key fire risk factors and their associated subfactors for new construction sites; (2) Developing a fire risk assessment model for measuring and comparing the overall fire risk levels of different construction sites; and (3) Providing a useful tool for users to identify high-risk areas and adopt remedial measures to reduce fire risk in new construction sites.

Successful development of the fire risk assessment model can enable its use for the setting up of a useful tool for easily and promptly measuring and comparing the overall fire risk levels of various construction sites within an organisation, between organisations and within the construction industry as a whole leading to an improved fire safety culture. A composite overall fire risk score, which is representative of all essential fire risk factors and subfactors on a construction site, will be derived by the model to provide a single measure of fire risk. The overall fire risk score can be monitored throughout the entire construction period for any one site. By adopting the developed fire risk assessment model, project managers, safety managers, safety officers, fire safety engineers and other related construction personnel could objectively assess the overall fire risk levels of their individual construction sites and prioritise improvement measures for the high-risk areas.

Although the proposed research study will primarily focus on the prevailing situation in Hong Kong, the research methodology may be replicated in other parts of the world, and may lead to international comparisons of the fire safety culture from place to place. It will also begin to expand the current body of knowledge about the relationship between fire safety culture and fire events and how these compare internationally.

7. ACKNOWLEDGEMENTS

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project entitled "Development of a Fire Risk Assessment Model for New Construction Sites in Hong Kong" with several research objectives sharing common background of study and research methodology.

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A REVIEW OF ICTAD STANDARD BIDDING DOCUMENT 02 (2007) FOR MAJOR CONTRACTS

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ABSTRACT

For every type of construction contract a set of Conditions of Contract is an essential constituent for its sustainability. Conditions of Contract create a legal framework with rights and obligations of the parties under which the parties are to operate. The two types of Conditions of Contract, i.e. a) Conditions of Contract drawn up by parties to the contract and b) Standard Conditions of Contract published by independent professional organisations have inherent advantages and disadvantages. A set of Standard Bidding Documents have been published by the Institute for Construction Training And Development (ICTAD) to be used within Sri Lankan construction industry out of which Standard Bidding Document 02 (SBD 02) is intended for major contracts. Since the usage of SBD 02 is only limited to construction industry of Sri Lanka, literature is somewhat scarce in regard to the limitations of Conditions of Contract of SBD 02. Therefore, the aim of this study is to explore the limitations of the Conditions of Contract of SBD 02.

Research problem was approached through a series of semi-structured interviews with local Consultant Quantity Surveyors who are currently practicing in private sector of Sri Lankan construction industry.

Findings of this research render that there are limitations associated with Conditions of Contract of SBD 02 which are affecting the sustainability of the application of SBD 02. Those limitations are required to be addressed in order to enhance the quality of SBD 02.

Keywords: *Conditions of Contract; Consultant Quantity Surveyors; Standard Bidding Document.*

1. INTRODUCTION

Ashworth (1991) explained that the term 'form' stands for a peculiar procedure associated with the expression of agreement. This formality gives a binding character to the agreement. According to Bunni (2005), standard forms of contract ensure the optimum protection of one or both parties' interest.

Due to multi party involvement and higher risk associated with construction industry, standard forms of contract are widely used in construction industry. Bunni (2005) pointed out that, it ensures a common basis for the comparison and evaluation of tender. The people, who are using a particular standard form of contract continuously, will become familiar with its strengths, limitations and the suitability to their own purpose. It can be considered as the foremost advantage of using a standard form of contract. Clough and Sears (1994) stated, "Standardisation of contract forms has done much to eliminate areas of disagreement among owners, architect- engineers and contractors" (p.143).

According to Bunni (2005), standard forms of contract which were developed by reputed independent professional organisations are more preferable rather than the standard forms of contract which were developed by parties to the contract. There are widely used and internationally accepted standard forms of contracts such as Federation Internationale Des Ingenieurs-Conseils (FIDIC), Joint Contracts Tribunal (JCT) and World Bank. The general contents of almost all these forms are similar. But there are wide differences in the detail and interpretation of some clauses.

Ashworth (1991) explained that most of standard forms of contracts contain three main sections. They are articles of agreement, Conditions of Contract and appendix to Conditions of Contract. Out of above

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mentioned three sections, Conditions of Contract create a legal framework that establishes relationship of the parties to the contract.

Main purpose of the Conditions of Contract is to prescribe the rights and obligations of parties connected to the contract. Claims, problems can be arisen due to limitations of Conditions of Contract. Those claims can badly affect to the sustainability of the construction project.

Sri Lanka has its own standard forms of contract published by Institute for Construction Training and Development (ICTAD). Those were prepared largely based on international standard forms of contract such as FIDIC and World Bank Conditions of Contract. ICTAD published set of standard forms of contract such as Standard Bidding Document 01 (SBD 01), SBD 02, SBD 03 and SBD 04. Even though, standard forms of contract published by ICTAD have been prepared largely based on international standard forms of contract, there are some deviations from international standard forms. This study addressed the question of "what are the limitations of Conditions of Contract of SBD 02 (2007) for Major Works, which can affect the sustainability of a construction contract?"

To achieve the above mentioned aim, it was found necessary to achieve the following objectives:

- To identify the advantages and limitations of using standard forms of Conditions of Contract;
- To identify the aspects to be considered when evaluating Conditions of Contract;
- To propose modifications to address the limitations of the Conditions of Contact of SBD 02 (2007) for major contracts.

The paper is basically organised as follows. The research gap was discovered under the next heading. Then the limitations of the study were discussed. An overview of standard forms of Conditions of Contract was presented through a literature survey. After that, the research methodology was described. Finally, research findings were presented along with the conclusions.

2. RESEARCH GAP EXPLORATION

Technology, rules and regulations regarding the construction industry can be varied from country to country. As far as a country is considered, it is foremost important to have a set of standard Conditions of Contract which has been prepared considering the construction context of the respective country.

SBDs were published considering Sri Lankan construction industry. It is foremost important to identify and address the limitations of Conditions of Contract of SBDs to increase the usage of SBDs. De Zoysa (1993) conducted a study regarding the suitability of the ICTAD SBD (1987) Conditions of Contract to Sri Lankan building construction. Since, the usages of SBDs are limited to Sri Lankan context, studies investigating the limitations of Conditions of Contract of SBD 02 (2007) cannot be found. Therefore, present study aims to identify the limitations of Conditions of Contract of SBD 02 (2007) which can affect the sustainability of the application of SBD 02.

3. LIMITATIONS OF THE STUDY

This study was restricted to Conditions of Contract of SBD 02 (2007). The research findings (limitations of Conditions of Contract of SBD 02 (2007)) are unique to SBD 02 (2007). Also, the interview survey was confined to senior Consultant Quantity Surveyors who are practicing in private sector.

4. STANDARD FORMS OF CONDITIONS OF CONTRACT

According to Ashworth (1991), in construction industry, there are many standard forms. Further he argued that the purpose of standardisation is to eliminate the areas of disagreements between parties. Besides, he explained that there is an increment in usage of such standard forms. Almohawis and Bubshait (1994) specified that "standardised conditions lessen the possibility of misunderstanding, undue compensation, the likelihood of change orders, and the occurrence of claims or litigation arising out of the contractual performance" (p.133). There are both advantages and disadvantages of using standard Conditions of Contract. For Sri Lankan construction contracts FIDIC documents, SBDs are widely used as standard Conditions of Contract.

4.1. *ADVANTAGES OF USING STANDARD FORM OF CONTRACT*

4.1.1. *DOCUMENTS ARE MORE ACCURATE DUE TO PERIODICAL REVIEW AND REVISE*

According to the study by Davis (as cited in Kumarasinghe, 2010) standard Conditions of Contract documents are reviewed and revised periodically. Therefore, the clauses are updated with the changes in law and practice. Also the possibilities of missing important clauses, adding vague clauses will be minimised in standard Conditions of Contract. Apart from that, current clauses will be altered according to the new laws and trends in construction industry. Therefore accuracy of the standard Conditions of Contract is higher than the Conditions of Contract drawn by parties to the contract.

Therefore, higher level of accuracy can be considered as a major advantage of using standard forms of contract.

4.1.2. *WIDELY ACCEPTED*

Davis (as cited Kumarasinghe, 2010) in his study mentioned that one of the main advantages of using standard Conditions of Contract is that they are widely accepted.

Apart from that, Clough and Sears (1994) stated following: "Standard forms have the advantage that their record of use has proven them to be both equitable and workable, and many of the provisions have been tested in the courts" (p.143). Those widely accepted standard Conditions of Contract can be used in any country in the world. FIDIC, NEC (New Engineering Contract) and JCT can be shown as examples. Similarly Senevirathne (2005) stated that, "Conditions of Contract drawn up by reputed independent professional institutes rather than the parties to the contract are much more likely to gain acceptance of all concerned" (p.6). Standard Conditions of Contract are periodically reviewed and revised. Also new clauses will be added according to changes in laws and new construction trends. Therefore accuracy of the Conditions of Contract is high. This also can be considered as another reason for widely acceptance.

Therefore standard Conditions of Contract are widely accepted, it can be considered as another advantage of using them.

4.1.3. *PROMOTE EFFICIENCIES OF ALL PARTIES*

Almohawis and Bubshait (1994) stated that, efficiencies of the clauses of Conditions of Contract will be tested and the areas of inefficiencies will be corrected. According to Bunni (2005), standardisation has been done for the purpose of the efficiency. He explained that efficiency will be increased from the repeated use of the standard Conditions of Contract.

Kwakye (as cited in Senevirathne, 2005) described the following:

> The use of standard conditions of contract would promote efficiency of all parties involved by obviating of the need to work with different Contract conditions in respect of each contract and enabling the accumulation of experience gained from their repeated use (p.6).

Furthermore, he described that "such standard forms of contract are intended to reduce the inefficiencies associated with the repeated drafting and reviewing of contracts and to facilitate a greater sense of partnership between Contractors and Employers" (p.6). Finally it is clear that, standard Conditions of Contract promote efficiency between all the parties.

4.1.4. *PARTIES BECOME FAMILIAR WITH THE CONTENT WITH THE FREQUENT USAGE*

Ashworth (1991) argued that, people who use it regularly become conversant to its contents. Also they would be familiar with its strengths, weaknesses and suitability for their own specific purposes. Similarly, Kwakye (as cited in Jayamanna, 2001) emphasised that the major advantage of adapting a standard form is, people who use it frequently become familiar with the passage of time.

As a final point, it can be said that with the frequent usage of standard Conditions of Contract, parties become familiar with their content reducing inefficiencies.

4.1.5. REPRESENT A DEGREE OF FAIRNESS IN A CONTRACT BETWEEN PARTIES

Almohawis and Bubshait (1994) specified that fairness of Conditions of Contract is very important and Conditions of Contract should be fair to all parties. Bunni (1997) stated that standard Conditions of Contract help to make the contract a fair and just contract. Similarly, Kwakye (as cited in Rodrigo, 2009), specified that standard Conditions of Contract detailed a degree of fairness. Likewise, Gayan (2003) stated that, standard Conditions of Contract fairly allocate risk and responsibilities between parties. In standard Conditions of Contract, risks were allocated to the best party who can control and mitigate risk. Therefore fairness of standard Conditions of Contract is high, compared to Conditions of Contract drawn up by parties to the contract.

Therefore it is clear that standard Conditions of Contract represent a degree of fairness in contract between parties.

4.1.6. MITIGATE PROJECT RISKS

According to Kwakye (as cited in Rodrigo, 2009), standard Conditions of Contract denote a degree of fairness in a construction contract between two parties by signifying a fair allocation of project risk between Contractor and Employer. Similarly Senevirathne (2005) stated following:

> The application of standard forms of contract helps to manage and mitigate project risks, as risks which may be overlooked under the pressure of tight project deadlines are likely to have been addressed during the multitude of document review by industry experts (p.6).

Michelson (2013) argued that, in construction industry, the project risk will be mitigated by allocating risks for the party who is mostly capable of controlling risk. Standard Conditions of Conditions are fair to all parties and risk will be allocated between parties fairly. Consequently, Conditions of Contract help to mitigate the project risks.

4.1.7. SAVE TIME AND MONEY

Almohawis and Bubshait (1994) explained that familiarity of the contracting parties with the standard Conditions of Contract will help to minimise the time and effort to prepare and review Conditions of Contract. Senevirathne (2005) described those standard forms of contract are planned to limit inefficiencies due to repeated drafting. Drafting Conditions of Contract should be done by experts. Also it takes a considerable passage of time.

If parties use a standard form of contract for their construction contract they do not want to prepare their own Conditions of Contract. Therefore, the parties can save their money and time.

Moreover, standard conditions of contract make both parties familiar with their rights and obligations, minimise delays and unexpected additional costs and minimise contractual disputes between parties. Those can be taken as other advantages of using standard Conditions of Contract.

4.2. LIMITATIONS OF STANDARD FORMS OF CONTRACT

4.2.1. MAY NOT FIT FOR ALL SITUATIONS

According to Rajapakse (2004), standard Conditions of Contract are not always performing perfectly. Robert and Day (as cited in Rajapakse, 2004) explained that standard Conditions of Contract will be inappropriate to the particular contracting situation. Also, the philosophical assumptions which were used to prepare standard Conditions of Contract will not be suitable for another contracting situation.

Consequently, it is clear that inappropriateness of Conditions of Contract for all situations can be considered as a major limitation of standard Conditions of Contract.

4.2.2. ALTERATION OF CLAUSES MAY CAUSE PROBLEMS

Rajapakse (2004) expounded that since standard Conditions of Contract are not fit for all situations, standard conditions have to be amended by the parties to the contract. He explained that those amendments will be done by modification, deletion and addition of certain clauses. Moreover he argued that, due to alterations of standard Conditions of Contract, benefits of standardisation will be reduced. According to Kumarasinghe (2010), doing amendments to Conditions of Contract without an expert will lead single party or both parties to a dangerous situation. Therefore alteration of standard Conditions of Contract must be done by an expert. But that will consume additional money, time and effort.

Consequently, it is clear that alteration of standard Conditions of Contract must be done by an expert even though it consumes time and money without leading one party or both parties into dangerous situations.

5. PATENT AMBIGUITIES

The definition for ambiguity is following:

> Ambiguity is uncertainty or doubtfulness of the meaning of language. When language is capable of being understood in more than one way by a reasonable person, ambiguity exists. It is not the use of peculiar words or of common words used in a peculiar sense. Words are ambiguous when their significance is unclear to persons with competent knowledge and skill to understand them. (Ambiguity, 2008, para. 1)

"Patent ambiguity is an obvious inconsistency in the language of a written document" (Hill and Hill, 2005).

Patent ambiguities can be considered as one of the limitations of Conditions of Contract. There can be patent ambiguities in standard Conditions of Contract as well as Conditions of Contract drawn up by parties to the contract.

6. CONTRA PROFERENTUM RULE

Contra Proferentum rule can be identified as the interpretation against the draftsman. It is a universally accepted rule which will be applied in construction contracts also. According to this rule, the person who includes the particular clause would be liable for the ambiguities caused by that clause.

In construction contracts Employer is liable for patent ambiguities of standard form of contract. That is because the Employer is the person who has the responsibility of preparing Conditions of Contract.

7. ASPECTS TO BE CONSIDERED WHEN EVALUATING CONDITIONS OF CONTRACT

Almohawis and Bubshait (1994) explained about eleven aspects to be considered when evaluating Conditions of Contract (refer Table 1).

Table 1: Aspects considered in evaluation of Conditions of Contract

Aspect	Classification
Clarity	The ease with which the language of the general conditions can be understood and the absence of ambiguities.
Conciseness	The degree to which the general conditions are free from unnecessary (superfluous) information.
Completeness	The degree to which the general conditions cover all contractual aspects.
Internal consistency	The level of conflict (if any) between clauses of general conditions.
External consistency	The level of conflict (if any) between clauses of general conditions and other related regulations.
Practicality	The feasibility of implementing the requirements of the general conditions.
Fairness	The degree to which the general conditions are fair to the contracting parties.
Effect on quality	The degree to which the general conditions promote the meeting of the project's established requirements of materials and workmanship.
Effect on cost	The degree to which the general conditions promote the completion of a project within the estimated budget.
Effect on schedule	The degree to which the general conditions promote the completion of a project within the allocated time duration.
Effect on safety	The degree to which the general conditions promote the completion of a project without major accidents and injuries.

Source: Adapted from Almohawis and Bubshait (1994)

8. SBD 02 (2007)

SBD documents published by the ICTAD are used as standard Conditions of Contract in Sri Lankan construction industry. For different construction contracts, ICTAD has published different SBD documents. Up to now, ICTAD has published six SBD documents. SBD 02 is for contracts above Rs. 100 million. Also it can be used for contracts having lesser value but of complex nature. Conditions of Contract of SBD 02 were developed largely based on FIDIC Conditions of Contract (1999).

9. METHODOLOGY

This section presents the research methodology which was followed by the researcher throughout the study in order to achieve the aim and objectives.

9.1. DATA COLLECTION

Taylor (2010) stated that the designs which have narrative interpretation of data are called Qualitative approaches. In this study, as the research findings, Qualitative data was gathered. Therefore, it can be said that, this research is more towards Qualitative approach. Since this study was not aiming to explore something deeply and the time period for this study was limited, Surveys were used as the research approach.

Since this research involved in identifying the limitations of Conditions of Contract of SBD 02, which was kind of exploratory and opinion survey, semi-structured interview was the research technique for this study. For selection of senior Consultant Quantity Surveyors in Sri Lanka, Convenience sampling method was used considering the time constraints associated with the research.

Nine local, senior Consultant Quantity Surveyors who have been serving for more than fifteen years in the Sri Lankan construction industry (private sector) were interviewed in order to gather information.

9.2. DATA ANALYSIS

The qualitative data which was gathered through semi-structured interviews were analysed using the content analysis technique. To assist in Content analysis process NVivo (NUD*IST Vivo Version 8) produced by Qualitative Solutions and Research Ltd. Was used.

10. RESEARCH FINDINGS AND ANALYSIS

This section presents the limitations of Conditions of Contract of SBD 02 which were found out through semi-structured interviews and proposes modifications to address these limitations.

10.1. SUB CLAUSE 1.1.2.4 (DEFINITION OF THE ENGINEER)

According to this Sub-Clause, in absence of Engineer is named in Contract Data, the Employer himself can be the Engineer. This will be a major problem which leads to disputes. Employer being the Engineer is unfair to the Contractor.

The sentence "In the absence of such appointment the Employer himself" (Ministry of Housing and Construction, 2007, p.40) should be removed from this Sub-Clause.

10.2. SUB CLAUSE 3.3 (INSTRUCTIONS OF THE ENGINEER)

According to this Sub-Clause, always Engineer's instructions have to be given in writing. It is impractical because most of the times, the Engineer issues verbal instructions.

There should be a provision mentioning that the Contractor should be able to confirm the Engineer's verbal instructions by sending a 'Confirmation of Verbal Instruction' (CVI) to the Engineer.

10.3. SUB CLAUSE 4.2 (PERFORMANCE SECURITY)

In this Sub-Clause the situations where the Employer can claim for the amount of Performance Security have not been given. The completeness of this sub-clause is less.

The situations where the Employer can claim for the amount of Performance Security should be mentioned. According to FIDIC there are four situations.

10.4. SUB CLAUSE 12.1 (WORK TO BE MEASURED)

The extent to which the re-measurements should be done is not mentioned properly. Clarity of this Sub-Clause is less.

The situations where the re-measurements should be done have to be mentioned. SBD 02 does not reveal about the situations where re-measurements should be done. Whether the errors in BOQ should be considered as Variations is a problem.

10.5. SUB CLAUSE 12.3 (EVALUATION)

The 2nd requirement, "change in quantity multiplied by such specified rate for this item exceeds 1 % of Initial Contract Price" (Ministry of Housing and Construction, 2007, p.74) is difficult to fulfil. Therefore, this Sub-Clause is impractical.

The 2nd requirement should be, "change in quantity multiplied by such specified rate for this item exceeds 0.01 % of Initial Contract Price".

10.6. SUB CLAUSE 13.4 (PROVISIONAL SUMS)

b) ii) of this Sub-Clause should contain the attendance fee also. Not adding attendance fee is unfair to the Contractor because, if the Work to be sub contracted, the Contractor should be paid for the services supplied for the Sub-Contractors by himself.

Attendance fee should be added to b) ii) of this Sub-Clause.

10.7. SUB CLAUSE 14.8 (PAYMENT OF RETENTION)

This Sub-Clause does not contain the way of releasing the Retention Money in the circumstances of issuing of Taking over Certificate only to part of the Works. Therefore, the users faced the problem of calculating Retention Money for part of the Work. Therefore, the completeness of this Sub-Clause is less.

The method of releasing the Retention Money when Taking over Certificate has been issued to a part of the Work and the method of calculating Retention Money for such situations must be included to this Sub-Clause.

10.8. SUB CLAUSE 15.5 (EMPLOYER'S ENTITLEMENT TO TERMINATE)

According to this Sub-Clause, the Employer has to hand over his project to another Contractor one year after the Termination. That is unfair to the Employer because his project will be delayed by another year due to this Sub-Clause. Once the parties terminate the contract they have their own rights to do whatever they wish. After the Termination, the Employer should have the power to assign another Contractor to his project as soon as possible in order to get the benefits from the project earlier.

The part "After this termination, the Employer shall not be precluded from executing the Contract himself or by another Contractor, after a period of one year lapsed …" (Ministry of Housing and Construction, 2007, p.86) should be deleted from this Sub-Clause in order to avoid that unfairness.

10.9. SUB-CLAUSE 19.1 (CONTRACTOR'S CLAIMS)

Not having a time bar for the Contractor to submit his claims can be considered as a limitation. Because of not having a time bar clause, the Contractors tend to submit their claims during any time of the project duration. Therefore, the Engineers faced difficulties in evaluating such claims because those incidents happened a long time ago.

The consistency of this Sub-Clause is less. At the last paragraph of this Sub-Clause it is mentioned about a 2nd paragraph which is actually not included in this Sub-Clause. The last paragraph of this Sub-Clause has been drafted assuming that there is a time bar clause as the 2nd paragraph.

It is better to add a time bar clause for submitting Contractor's claims as the 2nd paragraph of this Sub-Clause. Then the inconsistency of this Sub-Clause can be avoided.

10.10. SUB-CLAUSE 19.3 (PROCEDURE FOR ADJUDICATION)

In this Sub-Clause, it is mentioned that, "In the event the Parties are unable to reach agreement on the appointment of the Adjudicator within (14) Days from the date of such request, either Party may make an application to the ICTAD to appoint an Adjudicator" (Ministry of Housing and Construction, 2007, p.92). But practically, ICTAD is not maintaining a list of Adjudicators to appoint if two parties made such a request.

ICTAD has to maintain a list of experienced and qualified Adjudicators to appoint upon a request of two parties. ICTAD should be able to respond for such requests as soon as possible.

If not the power of appointing Adjudicators for a contract should be passed to the judge (Litigation system).

10.11. HAVE TO GET THE PRIOR APPROVAL OF THE ICTAD TO DO THE CHANGES

In the Guideline of SBD 02, it is mentioned following:

> Modifications or amendments to the Volume 1 of this bidding document should not be done unless they are really essential. Any such changes should be provided only in the Volume 2, Section 2-Bidding Data and Section 4- Contract Data as amendments to Instructions to Bidders and Conditions of Contract respectively only with the prior consent of the ICTAD." (Ministry of Housing and Construction, 2007, p.v)

According to this statement the parties have to get prior approval of the ICTAD, if they wish to do a change to SBD 02. This is impractical and this statement makes the SBD 02 a rigid document. If the parties think to change the Conditions of Contract of SBD 02, there is no procedure in ICTAD to correct the Conditions of Contract agreed by parties and approve it and return it to the parties.

10.12. LIMITATIONS IN DISPUTE RESOLUTION PROCEDURE

The clarity of dispute resolution procedure mentioned under Clause 19 (Claims, Disputes and Arbitration) is less. Not including "Amicable Settlement" as a one step of the dispute resolution procedure is a limitation. This procedure only has the dispute resolution feature. Dispute avoidance feature has not been included.

It is important to redraft the Sub-Clauses under Clause 19 avoiding loopholes and improving the clarity of the Clause. DAB (Dispute Adjudication Board) should be introduced as the method of adopting Adjudication, since DAB has the dispute avoidance feature.

If the parties are dissatisfied with the decision of DAB, parties should be encouraged going for "Amicable Settlement" without directly heading to Arbitration.

10.13. NOT HAVING CONDITIONS FOR SUB CONTRACTS

There is no any SBD document containing Conditions of Contract for sub contracts. When parties use SBD 02 as their Conditions of Contract, they have to draft Conditions of Contract for sub contracts by themselves. Not having Conditions for sub contracts is unfair to the Employer because he has to pay additional money to get it drafted.

It is important to add Conditions of Contract for sub contracts to SBD 02.

10.14. LESS TIME DURATIONS PROVIDED FOR EACH WORKS

For most of works, SBD 02 provides only 14 days and it is impractical. In Sub-clause 8.1 (Commencement of Works), the construction work should be started within 14 days after the Contractor receives the Letter of Acceptance. If the project is massive, 14 days will not be enough for commencement.

Moreover the Contractor must submit the Programme within 14 days after the notice of commencement. For a construction project the Programme is critical.

Therefore, to do a Programme properly, the Contractor should be given sufficient time. To develop a Programme for a massive construction 14 days will not be enough.

Sufficient time durations should be given for each work.

10.15. NOT HAVING PROVISIONS TO COVER NON NEGLIGENCE INSURANCE

Damages can be happened to a 3rd party due to the construction process which could not have been foreseen and are not attributable to negligence of the Contractor/Engineer. There should be non-negligence insurance to cover up such damages. But SBD 02 does not provide a Sub-Clause for non-negligence insurance. Not having a Sub-Clause for non-negligence insurance can be majorly unfair to the Employer.

It is important to have Sub-Clause covering non-negligence insurance.

10.16. SOME ESSENTIAL SUB-CLAUSES WERE NOT INCLUDED TO SBD 02

It is a major disadvantage that not having a Sub-Clause for Employer's financial arrangements. Not having that Sub-Clause is unfair to the Contractors.

Moreover Sub-Clauses for "Replacement of Engineer", "Electricity, Water, Gas", "Employer's Equipment and free-issue materials", "Engagement of Staff and Labour", "Manner of Execution", "Surface requiring Reinstatement", "Right to Access" and "Schedule of Payments" have not been included in SBD 02. Without having the above mentioned Sub-Clauses it is difficult to fulfil the requirements of the project.

"Employer's Financial Arrangements" and other important Sub-Clauses should be added to SBD 02.

10.17. NOT HAVING PROVISIONS FOR BOI (BOARD OF INVESTMENT) PROJECTS

In Sri Lanka there are a lot of BOI (Board of Investment) projects. For such projects, parties have to undergo different procedures. Therefore, all Conditions that are used in general contracts cannot be applied for BOI projects.

It is important to have set of provisions for BOI projects.

10.18. LESS INTERNAL CONSISTENCY OF THE CONTENTS OF SBD 02

Basically, SBD 02 was prepared amending Conditions of Contract of FIDIC 1999 (Red Book). Most of changes were done, deleting some parts of the provisions of FIDIC. Some internal inconsistencies can be identified in SBD 02 due to deleting some parts of the provisions. Sub-Clause 19.1 can be mentioned as an example.

The redrafting of the areas having inconsistencies is advisable.

10.19. NOT HAVING PROVISIONS TO COVER CO-LATERAL WARRANTIES

There is no any Sub-Clause for co-lateral warranties in SBD 02. It is unfair to the end users of the property. It is important to have a Sub-Clause regarding co-lateral warranties in order to safeguard the end users.

11. CONCLUSIONS

Conditions of Contract are essential for construction contracts due to the high risk involved with the construction projects. The limitations of Conditions of Contract can affect to the sustainability of a construction contract.

For the usage of Sri Lankan construction industry ICTAD has published a set of Standard Bidding Documents, out of which SBD 02 is for major construction contracts.

Conditions of Contract for a construction project can be considered as a must, since they specify the rights and obligations of the two parties. The standard forms of contract which consists of standard Conditions of Contract help to eradicate the areas of disagreements between parties. There are advantages and limitations in using standard Conditions of Contract.

The aim of this study was to identify the limitations of Conditions of Contract of SBD 02 (2007). The limitations of Conditions of Contract of SBD 02 have been identified and suggestions for improvements have been presented in this study.

According to the results of the study there are some limitations in the SBD 02 which require addressing. Those limitations make entanglements between parties to the contract, affecting to the sustainability of the construction contracts. Usage of SBD 02 in Sri Lankan construction industry can be increased by addressing those limitations.

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AN EVALUATION OF BIM ENABLED COST MANAGEMENT IN MEETING SUSTAINABILITY TARGETS

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ABSTRACT

With the current UK Government drive towards the adoption of Building Information Modelling (BIM), the Quantity Surveyor (QS) must possess the necessary knowledge and skills to use BIM as part of their cost management duties. For the purposes of this paper BIM contributes to Sustainable Construction Practices by facilitating efficient and effective integrated team working whereby, from the point of view of cost management, the process of planning and controlling maximises client value, minimises waste and optimises whole life cycle costs. The UK government expects cost management to utilise BIM automated quantity take-off where appropriate to facilitate Level 2 compliance by extracting 3D BIM model quantities into Excel and costing the quantities manually. BIM can directly benefit cost management by rapid and accurate automated quantity take-off; facilitating cost planning and Bill of Quantity production aimed at more effective use of resources. This paper will consider how the QS role will develop in relation to cost management in the new BIM era and how effective BIM will be in ensuring cost management helps meet sustainability-related targets. To inform the findings reported in this paper data was collected through exploratory interviews with QS's from three private practices, three contracting organisations and two experts in the field of BIM. This research suggests that whilst BIM is being utilised by the profession it is not standard in its application and not being utilised in relation to life cycle decisions thus limiting its impact on helping to meet sustainability targets.

Keywords: *BIM; Cost management; Role of a QS; Sustainability.*

1. INTRODUCTION

BIM is the new Construction industry buzz word and is seen to be one of the solutions to the construction industry's much documented problems. BIM is a 3D model designed to encapsulate data to simulate the entire construction and lifecycle of a building. As well as showing the building form and construction, the model has the potential to display scheduling, quantities and costs, lifecycle maintenance, energy consumption alongside health and safety information (Kamardeen, 2010). By offering a common platform that facilitates and encourages collaboration, it has been prophesised that more accurate, effective and better informed decisions will be made in relation to construction projects. It offers the potential to reduce waste by moving away from the traditional 2D drawings to a much more effective digital 3D environment, reducing the time spent in decision making and minimising the opportunity for errors. BIM can therefore be said to be contributing to sustainable construction practices by facilitating efficient and effective integrated team working. The changes that BIM will undoubtedly bring to the industry and current work practices is the focus of this paper, which aims to explore the impact BIM will have on the role of the QS in the UK. Particular emphasis will be given to assessing its impact on the current duties of the QS including: procurement advice, cost estimates, cost planning, value engineering, tender estimates, bills of quantities, whole life costing, budgetary control, valuations, financial reports, cash flow control and final account calculation (Cartlidge, 2013, Ashworth and Hogg, 2007). The findings reported in the paper are part of a wider research project which is currently ongoing.

The construction sector is one of the largest employers in the UK. It is estimated that the industry is made up of 300,000 firms employing over 2 million people in various roles (BIS, 2012). The value that construction brings to the UK economy is vast, accounting for approximately 6.3% of GDP in 2011 (BIS 2012). It has over a period of time been subject to numerous government reports to encourage improvements in productivity and predictability from Michael Latham's report 'Constructing the Team' (1994) to John

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Egan's reports 'Rethinking Construction' (1998) and Accelerating Change (2002) and more recently the Andrew Wolstenholme report 'Never Waste a Good Crisis' (2009). All reports conclude that the industry still has some way to go in providing a more standardised leaner industry and in resolving the issues of fragmentation and waste. In an attempt to once and for all address many of these issues the Government have recently introduced the Government Construction Strategy (2011) that identifies BIM as a tool to help improve the performance of the construction industry, reduce waste and improve collaboration. The Government set out a 5 year plan that states public funded projects over £50m (later changed to £5m) should be utilising BIM at a maturity level 2 by 2016. Level 2 maturity is a managed 3D environment with separate discipline 'BIM' tools data attached. This level of BIM may utilise construction sequencing and/or cost information. The Government, by mandating maturity Level 2, have committed construction project teams to provide their own distinct outputs by using BIM and managing it via a series of self-contained models using proprietary information connections between each of the project teams own distinct systems.

It is important that consideration is given as to how the QS can comply with BIM maturity Level 2. The UK Government Building Information Modelling (BIM) Strategy paper for the CEEC meeting (BIS, 2011), states that Level 2 may utilise time and schedule data and cost data and that QSs should be familiar with BIM, and actively develop ways in which processes can be made more cost effective, add value and be more sustainable. Cost management is an essential element within large construction projects, especially when project cost is an important criterion. QSs are responsible for this function yet a recent survey undertaken by the RICS in 2011 revealed that only 10% of QSs regularly use BIM (BCIS, 2011). It is crucial that QSs integrate BIM within cost management, or risk marginalising themselves within public projects.

2. BUILDING INFORMATION MODELLING

The collection, management and utilisation of potentially multiple data sources bring with it many problems that may be overcome by the utilisation of information modelling. BIM is not a new development its origins can be traced to the early 1970's but more recently the impetus to its application has stemmed from the Government Construction Strategy 2011. The UK Government has stipulated that BIM should be adopted on all public projects by 2016. This provides a massive incentive to contractors and construction professionals alike to arrange their organisations train their staff and develop and utilise BIM tools and techniques from 2016, not least the Quantity Surveying profession.

BIM can be said to be about information about the entire building and a complete set of design documents stored in an integrated database, where the information is parametric and thereby interconnected. All changes within the model being instantly reflected throughout the rest of the project (Krygiel *et al.,* 2008).

More recently the UK Construction Industry Strategy has set out further targets including a 33% cut in construction costs, 50% faster delivery on projects and 50% lower greenhouse gas emissions in the built environment by 2025 (Construction 2025). BIM is one of the mechanisms that the UK government are hoping will support these targets. Today sees the challenge of ensuring that efficiencies brought about by the introduction of BIM 2016 are reflected in the roles of the construction professionals. There are many benefits that can be realised by the introduction of BIM. Generally it increases the speed and accuracy by which decisions can be made which will impact on the role of the QS. In construction there are many decisions to be made through the life cycle of a building and many different software packages being utilised to support and inform those decisions. The construction industry can utilise BIM for building visualisation, design appraisal, project management, information storage and retrieval, cost estimating structural analysis, on site management, facilities management and contract preparation (Sun *et al.,* 2008).

2. BIM AND SUSTAINABILITY

The UK Government is pushing both the private and public sectors to employ more effective sustainable construction practices as it will not only help the environment but it can also improve economic profitability and improve relationships with stakeholder groups. BIM is seen to be the impetus for these new efficiencies. The potential between BIM and sustainability is just beginning to be realised (Bynum *et al.,* 2013). Holness (2008) suggested that designers should consider a building as a fully integrated dynamic design and construction process. This could perhaps lend itself towards further life cycle analysis whereby the material schedules produce in BIM could be utilised to calculate operational efficiency and carbon usage. (Stadel *et al.*, 2011). Further developments in technology and improvements in interoperability will support BIM in assisting in the development of more efficient construction practices.

3. BIM AND THE QS

In 1971, the RICS defined the role of the QS as being associated with measurement and valuation (Nkado and Meyer, 2001). Nowadays this role has diversified to such an extent that the QS must develop a range of knowledge and understanding to satisfy the needs of a plethora of different employers and their roles. Ashworth and Hogg (2007) argued that their skills have been enhanced to meet current needs in relation to cost management of a construction project.

Cost management can be considered as the process of planning and controlling costs throughout the complete duration of a construction project (RICS, 2012). It is usually undertaken by a QS. The very term QS roughly translates into measurer and inspector of quantities. The UK government BIM adoption requirements are intended to drive the progression of BIM into cost management practice (BCIS, 2011a).

However, with the current UK Government drive towards BIM adoption the QS must now extend and refine their knowledge and understanding to ensure that they possess the necessary skills to apply BIM into cost management in practice. If cost management can be considered as the process of planning and controlling costs throughout the complete duration of a construction project (RICS, 2012), then it is necessary to assess how BIM can facilitate this process.

One of the advantages to the QS from BIM is the ability of QS or electronic quantity take-off and cost estimating (Eastman *et al.*, 2011). Eastman *et al.* (2008) stated that though most BIM applications allow direct quantity take off, additional 3rd party software is required for cost calculation and allowing linking of quantities to cost databases. Furthermore, cost can depend upon additional project specific conditions such as working space, requiring specific skills of a cost manager or estimator (Roginski, 2011, Gee, 2010).

There is still some uncertainty as to exactly what is required for cost management to achieve level 2 BIM compliance as required by 2016. The Government Construction Strategy (Cabinet Office, 2011) and the Report for the Government Construction Client Group Building Information Modelling (BIM) Working Party Strategy Paper (BIM Task Group, 2011) contain very little information about cost management. The strategy paper states that for level 2 compliance, quantities should be taken from the 3D model; suggesting BIM automated quantity take-off is required.

Currently the guidelines (BCIS, 2011a) states that level 2 may utilise programme data and cost elements and that clients should expect quantity surveyors to be familiar with BIM and actively develop ways in which processes can be made more cost effective and add value. The UK government wishes cost management to utilise BIM automated quantity take off where possible, but it is not yet a statutory requirement.

As COBie (the UK BIM Strategy recommended data exchange format) requires cost data in Excel format (BIM Task Group, 2011), then it should be possible to achieve level 2 compliance by extracting 3D BIM model quantities into Excel and costing the quantities manually. It follows that BIM can directly benefit cost management by rapid and accurate automated quantity take-off; facilitating cost planning and Bill of Quantity production. The automated quantity take off also facilitates cost control and analysis as the building model progresses, and allows easier pricing of alternative design solutions (Klashka, 2006, Eastman *et al.*, 2008). Level 3 BIM development will fully incorporate time and schedule data, cost dataand life-cycle data technology (BIM Task Group, 2011) and this will assist in fast and accurate calculation of life cycle costing (Azar and Brown, 2009, Jiang, 2011, Bartlett, 2011) which increasingly falls under the duties of cost management. Procurement and contractual advice can fall within the boundaries of cost management as the procurement strategy and risk allocation can have a great effect upon the cost of a project. There are documented examples that BIM can reduce overall project costs by between 5 and 10%, though the actual saving depends on the specifics of each project and the level of BIM integration (Eastman *et al.*, 2011, Lane, 2012). This could be considered another enabler for cost management: by formalising a procurement strategy that integrates BIM (and the associated cost advantages); a QS will provide the client with better value for money and contribute to sustainable construction practices.

Despite the above enablers, there is a wealth of documentation to suggest that QS's within the UK are lagging behind other construction professions (Klashka, 2006, Lane, 2012, BCIS, 2011a) in their uptake of BIM. The RICS carried out a survey about the use of BIM by its members (BCIS, 2011b). This survey is especially relevant as it targeted QS's within the UK and received 153 respondents. The survey found that only 10% of respondents regularly used BIM with a further 29% having had some BIM engagement.

The NBS conducted a BIM survey with around 1000 responses from different disciplines within the construction industry of which 5% were QSs (NBS, 2012). This is supported by estimates from Davis Langdon that BIM software and training will cost quantity surveying practises £2,000 per employee, and £5,000 for a 'super user' (Matthews, 2011).

QSs may reject BIM as they feel it threatens their job due to automation (Kennett, 2010, Rendall, 2011). This urgently needs to be investigated as QSs are expected to utilise BIM models on public funded projects by 2016. Should the industry fail to take advantage of BIM, architects and contractors may start to provide cost management duties based upon BIM models themselves, reducing the requirement for QSs to undertake this role (NBS, 2012, Rendall, 2011).

5. RESEARCH METHODOLOGY

The research methodology adopted must "be appropriate for the questions that you want to answer" (Robson 2002, p.80). The research methodology adopted is a pragmatist/post-positivist research philosophy to facilitate the linking of practice and theory using a mixed methods approach. It is important for this research that theory and practice are not kept separate. "We cannot afford to ignore theory for the sake of just the facts" (Ryan 2006, p.2).

The research was divided into 2 stages. The first stage covered a critical analysis of current literature and thinking in the field and the second stage qualitative data was gathered by undertaking semi structured interviews with BIM experts and QSs in the industry that reflected both the contractors and the clients' viewpoint in relation to the role of the QS.

The interview questions focussed on what these organisations understand by BIM and how BIM can be used by QSs in relation to cost management. Eight (08) interviews were undertaken with a selection of personnel from the construction industry. The eignt interviewees were spilt into 3 sets in order to effectively compare the findings.

The sets were as follows:

- Two (02) experts in the field of BIM
- Three (03) representatives from contracting organisations
- Three (03) representatives from private practice QS

The data were analysed using thematic analysis, with NVIVO10 utilised as a tool to support this process. The key themes were analysed across the three sets and were quantified by producing thematic profiles identified against the number of "passages" relating to each theme.

6. RESULTS

6.1 HIGH LEVEL THEMES

Four high level themes were derived from the interviews. Figure 1 provides a thematic diagram of the high level themes and associated sub-themes that were identified i.e. a high-level theme is "BIM impact on QS" and associated sub-themes are "traditional QS role", "benefits to QS role" and "survival of the QS".

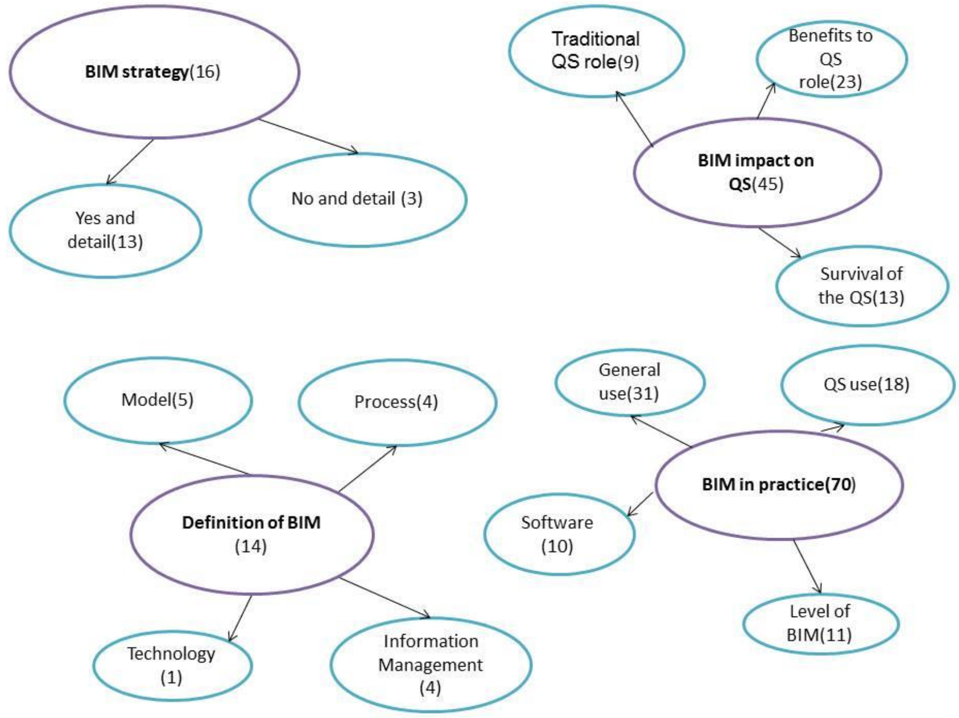

Figure 1: Thematic Diagram

A total of 145 related passages were established, in which the responses provided for each theme were fairly evenly distributed, however within each them there were distinctive differences in amount of responses from each interviewee set. This is illustrated in Table 1.

Table 1: Thematic Profile of High Level Themes

	A : Contractor	B : Expert	C : PQS	TOTAL
Definition of BIM	6	2	6	14
BIM strategy	5	3	8	16
BIM in practice	27	8	35	70
BIM impact on QS	17	7	21	45
Overall	55	20	70	145

6.2. THE DEFINITION OF BIM

The first key theme was ‘the definition of Building Information Modelling’, which produced 14 related passages: evenly distributed between the PQS (6 passages) and contractor (6 passages). This is illustrated below in Table 2. Sub themes were identified between the definitions in relation to how the interviewees choose to define BIM. One PQS interviewee stressed ‘*it’s the information as everyone says, it’s the “I” in BIM, so it’s how you manage information throughout the life of a project’*, whilst one Contractor identified it ‘*as a model, and it’s a set of protocols and it’s also a process and it’s the kind of the culture and the dynamics of the project itself*’ and another commented *‘the outputs from that model as a result of the process can range from anything from 2D drawings all the way through to cost estimates, programmes estimates’.* One BIM Expert confirmed ‘*it’s a series of models it’s no singular model*’. Only one passage referred to it being a technology.

Table 2: Thematic Profile: Definition of BIM

	A : Contractor	B : Expert	C : PQS	TOTAL
Definition of BIM				
Information Management	2	0	2	4
Model	2	0	3	5
Process	2	2	0	4
Technology	0	0	1	1
Overall	6	2	6	14

6.3. *BIM STRATEGY*

The second key was the 'the adoption of a BIM strategy', which produced 16 related passages, as shown in Table 3. It was found that all but one interviewee, a PQS, did have a BIM strategy although there was much variance in its format and visibility. One PQS interviewee identified many layers to their BIM strategy and emphasised '*Yes we've got one, well it's at two levels. At a group level we've got a whole lot of standards and protocols around delivering the project in BIM and then at a business level we've got a BIM strategy. In fact our BIM strategy is one of our strategic priorities for the business so it's something that's reported back in to the board every month*', whilst another PQS claimed '*No we don't. We do have a BIM working group. But what we do in terms of BIM, we develop strategies for clients'*.

Table 3: Thematic Profile: BIM Strategy

	A : Contractor	B : Expert	C : PQS	TOTAL
BIM Strategy				
Detail - no	0	0	3	3
Detail - yes	5	3	5	13
Overall	5	3	8	16

6.4. *BIM IN PRACTICE*

'The adoption of a BIM in practice' was the third theme, which produced a total of 70 related passages with four sub themes in relation to general use, level of BIM working at, current practice with the QS and the implications of the software. This is illustrated in Table 4.

Table 4: Thematic Profile: BIM in Practice

	A : Contractor	B : Expert	C : PQS	TOTAL
BIM in Practice				
General use	11	4	16	31
Level of BIM	5	2	4	11
QS use	5	2	11	18
Software	6	0	4	10
Overall	27	8	35	70

6.4.1. *GENERAL USE*

This sub theme received the greatest number of passages with 31 out of the total 70. A common statement was around BIM being used to aid collaboration and engagement and interaction on a project and to facilitate decision making '*throughout the entire business'*. It was also identified that BIM was being used very early on in the design process in relation to buildability and clash detection. **'***We're getting QS's to sit in on clash meetings and see when changes are made and understand reasons why the changes are made. It's as much about the beam has to be a larger beam so it will cost more but it's the associated costs, if we don't do that then the roof has to be strengthened and that will cost even more than the beam.'*

6.4.2. *Level of BIM*

All interviewees with the exception of one (01) PQS felt that they were working at between Levels 1 and 2. One PQS commented *'We work at the level of maturity that we can with the team and with the project and with the client. The majority is probably still not even at level 2'* with Contractors stating *'sort of working at about 1.8'*. This was supported by a BIM Expert *'let me tell you if everybody tells you they are at Level 2 they are lying to you'*.

6.4.3. *QS Use*

Eighteen (18) of the total seventy (70) passages related to current practice of BIM with the QS with 11 of the passages from the PQS. There was a variance in current practice and adoption of BIM. One PQS stated *' we are moving through to a BIM environment that whole kind of measurement and take off becomes much less'* whilst the Expert stressed that by adopting BIM practices this allowed them to move *'onto the big part of BIM itself , in terms of you are making more lifecycle decisions rather than just Capex decisions. It's more about total expenditure'*. This was contradicted by one PQS who stated *'I don't think our lifecycle costing team have used any models as yet.'* There was much discussion around the use of BIM for quantification particularly in relation to cost planning, with one Contractor claiming *'We're certainly using early access to quantities to test the validity of our cost plan and have been doing it right at the start of the bid on our Liverpool project'*.

6.4.4. *Software*

Ten (10) of the total seventy (70) passages related to software with the majority 6 of the passages from the Contractor. The majority of the passages discussed the decision around purchasing and trialling software. This was by a PQS and Contactor respectively: '*we are we are starting to look at perhaps software to be able to interrogate the design and check the design for compliance and for change so that they can cost that change as well'* and '*We're looking at software fairly frequently. We've got test models.'* Others discussed formatting issues around the various software's '*it's around can our software handle it in terms of taking off information for the model, it's not just a case of is it in the right format. You know we get DWFX files'*.

6.5. *The Impact of BIM on the QS*

The fourth key theme was the 'the impact of BIM on the QS', which produced 45 related passages. This produced 3 sub themes in relation to Benefits of BIM to the QS role, the traditional role of the QS and the survival of the QS, as shown in Table 5.

Table 5: Thematic Profile: BIM Impact on the QS

	A : Contractor	B : Expert	C : PQS	TOTAL
BIM impact on QS				
Benefits to QS role	9	3	11	23
Survival of the QS	3	3	7	13
Traditional QS role	5	1	3	9
Overall	17	7	21	45

6.5.1. *Benefits to the QS Role*

This resulted in the largest number of passages with 23 out of the total 45. On the whole the passages discussed creating efficiencies in the processing of information making the QS work smarter and facilitating faster more accurate decisions. Both the Contractor and PQS believe that *'the information flows a lot faster'* affording *'the QS more time to do what's not in the model, to see the gaps, to understand where things are missing'* and move into other areas not just the measurement of embodied and operational carbon but *'even in to the quantification of water as we are starting to see small examples of people talking about embodied water and operational water.'* Improvements in the method of communication was also seen to be a key benefit to the QS as they work collaboratively to make informed decisions with a PQS stating *' BIM will help us communicate the impact of cost better. I think if we're participating in federation meetings and we* *take a more collaborative project team approach then that must help us all work faster and more efficiently'* Risks were also identified as being reduced as the QS still has *'professional obligations to fulfil regardless of how the information is generated'* provided the model was set up appropriately to achieve the project outcomes. One contractor expressed some concern in relation to this *'what we find is that where the project has been set up well and where there's agreed structures and protocols around how the model would be developed then its considerably more efficient'*. This was one of the major caveats expressed by all experts that the model must be fit for purpose and set up so as to provide the appropriate information in the correct format to facilitate smarter more effective working.

6.5.2. SURVIVAL OF THE QS

Concern was expressed in relation to the role of the QS and how it must adapt in order to survive. One PQS was fearful how BIM might be used by contractors and thought it was *'just another evolution. And I think we are an adaptable service but the one thing that I think we could have as a challenge is the fact that contractors are trying to offer one stop shops'*. This was supported by another *PQS* who thought that *'we don't quite know how it's all going to fit together in terms of individual responsibilities at the moment'*.

The majority of the experts believed QS survival was about attitude and positivity. With one BIM expert stating '*I think that if QS's embrace BIM in a positive and constructive way then they've got a lot to offer the project team and the role of the QS will be strengthened. I think if QS's are negative or resistant or conservative about BIM then there is a potential that other members of the project team, and by that I mean architects, designers and structural engineers and so on will find different ways to deliver their projects. And in that sense the QS's role could be diminished'*.

All experts believed the role of the QS would survive the BIM revolution albeit in an amended form due to their flexibility and adaptability with one PQS asserting *'we might have to add some more strings to our bow'.* Whilst it was confirmed by all experts that the QS role was not endangered the QS business however was deemed to be under threat, as one BIM expert expressed *'The traditional QS firms might not survive'.*

7. CONCLUSIONS

This research suggests that whilst BIM is being utilised by the profession there is no standardise use and little evidence of it being utilised in relation to life cycle decisions. BIM has the potential to reduce the time spent by the QS in relation to the mundane routine measuring of quantities allowing cost management to be more efficient and accurate, thereby reducing waste in the construction process. There is little evidence to suggest that BIM adoption has made cost management more efficient and effective and does not as yet help meet sustainability related UK targets. BIM presents both challenges and opportunities for the profession, some have been slow to adopt and others less so. The QS profession will survive but they will need to respond to the changes brought about by BIM and adapt their practices. BIM strategy's need to be in place to support this change and people made aware of the potential of BIM to revolutionise the way in which they work.

The next stage of this research is to consider the barriers that prevent BIM-enabled construction and evaluate the changes it is likely to bring to the QS profession.

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ANALYSIS OF THE ANTI-CORRUPTION STRATEGIES IN THE CONSTRUCTION SECTOR OF CHINA

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ABSTRACT

While various anti-corruption strategies (ACSs) have been developed to curb the widespread corruption in the construction sector, effectiveness of these ACSs has seldom been investigated. This study, therefore, aims to identify and evaluate the ACSs being implemented in China. To achieve these objectives, a comprehensive literature review and a two-round Delphi survey of 14 experienced industry experts and academics were conducted. Survey results reveal that the most effective ACS is legal framework, followed by penal sanction, regulations, positive leadership, adequate institutions, transparency, economic sanction, administrative sanction, and education and training. Also, the results show that the effectiveness of raising the wage level as an anti-corruption strategy did not receive a high evaluation by the Delphi panel. Findings of this study can help enhance a better understanding of anti-corruption strategies and thus improve a corruption-free environment.

Keywords: *Anti-Corruption Strategies; Construction Sector; China; Delphi Survey.*

1. INTRODUCTION

Construction has been consecutively regarded as the most corrupt sector according to the Bribery Payer Index published by the Transparency International (1999, 2002, 2006, 2008 and 2011). This may be because that the construction sector is fragmented in nature as a result of involving clients, designers, contractors, consultants, and suppliers, which imposes difficulties in tracing of payments and information and the diffusion of standards of practice (Kenny, 2009). Similar to other developing countries, China faces a considerable challenge of preventing corruption because of imperfect legislation and administrative systems (Zou, 2006). The National Bureau of Corruption Prevention of China revealed that 15,010 persons were prosecuted for corruption in the construction sector between 2009 and 2011, and the amount of corruption reached USD 490 million (Xinhua Net, 2011). Such a serious situation has forced the government to increase their focus on anti-corruption issues and strengthen relevant supervision in the Chinese construction sector.

Various anti-corruption strategies (ACSs), such as leadership, rules and regulations, training, and sanctions, have been proposed to prevent corruption in the construction sector (Zou, 2006; Sohail and Cavill, 2008; Tabish and Jha, 2012). However, the effectiveness of these strategies has been seldom systematically evaluated before. Therefore, in the context of Chinese construction sector, this study aims to evaluate the

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effectiveness of ACSs that is being implemented by a two round Delphi survey. Two specific questions will be addressed in this study:

- What are the ACSs being implemented in the construction sector of China?
- Which of these ACSs have higher effectiveness?

2. LITERATURE REVIEW

Considerable efforts have been made to develop anti-corruption strategies in the construction sector of China. For instance, Hu and Guo (2001) and Tan *et al.* (2011) believed that positive leadership plays an important role in the issue of anti-corruption because an upright leader communicates values of integrity to the rest of the organisation and creates conditions that motivate people to behave in an upright way. Ge (1994) and Long and Tian (2008) reported that a completed legal framework can effectively ensure fairness and transparency in the construction sector and curb corruption. Ge (1994) and Wu and Yao (2008) stated that sound systems, including a scientific decisions making system, a thorough supervision system, and a wholesome credit guarantee system, can help prevent individuals from resorting to corrupt practices. Wang and Ni (2004) and Nan and Meng (2008) reported that rigorous execution of laws and rules is crucial to corruption prevention otherwise any law or rule proposed will be useless. He (2004) believed that transparency mechanism is an effective anti-corruption strategy because it can provide the public with access to information on construction projects so that project processes can be monitored. Wu *et al.* (2008) and Long and Tian (2008) stated that raising the wage level for industry practitioners can effectively decrease their potential attempt of performing corrupt practices. Xia and Zhang (2005) stated that the education and training of industry practitioners on anti-corruption practices could help establish a sound corporate culture for the prevention of corruption. Wu *et al.* (2008) and Xie and Kang (2010 and 2011) reported that, effectiveness of anti-corruption strategy of sanction, including an administrative sanction, economic sanction, and the penal sanction, has also been supported widely. Based on the above review, a list of ten (10) ACSs currently advocated in the construction sector of China was identified from literature as shown in Table 1.

Table 1: Anti-Corruption Strategies Identified from Literature

Anti-Corruption Strategy	**Source**															
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**
Positive leadership		√							√			√				
A completed legal framework	√		√										√			
Sound systems	√						√							√		
Rigorous execution of laws and rules				√									√		√	
Transparency mechanism											√					
Raising wage level			√			√										
Education and training					√											
Administrative sanctions												√				√
Penal sanctions								√		√						√

Note: A = Ge (1994); B = Hu and Guo (2001) C = Long and Tian (2008); D = Nan and Meng (2008); E = Xia and Zhang (2005); F = Wu *et al.* (2008); G = Wu and Yao (2008); H = Xie and Kang (2010); I = Tan *et al.* (2011); J = Xie and Kang (2011); K = He (2004); L = Zhou and Liu (2004); M = Li and Li (2004); N = Lv and Liu (1999); O = Wang and Ni (2004); P = An *et al.* (1999)

3. RESEARCH METHOD

A two-round Delphi survey was employed to evaluate the effectiveness of these 10 ACSs identified from the literature. The Delphi method is a structured communication and consensus building approach amongst a group of experts on a complex problem (Chan *et al*., 2001; Hallowell and Gambatese, 2010). This method refers to an iterative process where consensus is often reached through rounds of feedbacks of experts' opinion and judgment on a particular subject (Hon *et al.*, 2012). The selection of experts is crucial to secure the quality of a Delphi survey (Chan *et al*., 2001; Hallowell and Gambatese, 2010). Therefore, the following criteria were employed to identify eligible panel members for this Delphi survey: (1) at least 10 years of experience in the construction sector, (2) senior positions in their organisations, (3) various professional backgrounds, and (4) different geographic backgrounds across the country. In this study, a Delphi panel constituting 14 experts that satisfy the above criteria was established to facilitate the survey. Table 2 shows the backgrounds of these experts.

Table 2: Backgrounds of Interviewees

No.	Employer	Position	Years of Experience	Working Place*
A	Government	Director	20	Eastern developed areas
B	Government	Deputy Director	16	Central and western developing areas
C	Client	Project Manager	19	Eastern developed areas
D	Client	Project Manager	17	Eastern developed areas
E	Client	Director	13	Central and western developing areas
F	Contractor	General Manager	25	Eastern developed areas
G	Contractor	Project Manager	20	Central and western developing areas
H	Contractor	Director	15	Central and western developing areas
I	Consultant	General Manager	20	Eastern developed areas
J	Consultant	Project Manager	16	Central and western developing areas
K	Consultant	Project Manager	15	Central and western developing areas
L	Academic	Professor	22	Eastern developed areas
M	Academic	Professor	17	Central and western developing areas
N	Academic	Associate Professor	13	Eastern developed areas

Note: *Working places are divided into eastern areas with GDP per capita above USD 8,000, and central and western areas with GDP per capita below USD 5,000, according to the National Bureau of Statistics of China (2012).

In the first round of Delphi survey, the panel members were requested to provide their evaluation on the effectiveness of the 10 ACSs using a five-point rating system (i.e., 1 = very ineffective, 2 = ineffective, 3 = neutral, 4 = effective, and 5 = very effective). Then the mean scores of evaluations of these ACSs were calculated and returned to the Delphi panel in the second round of the survey. In the light of the feedback, the panel members were requested to reconsider their evaluation and reassess these ACSs. To assess the consistency among the Delphi panel, Kendall's Coefficient of Concordance (W) was calculated as recommended by Hon *et al.* (2012). The consistency can be proved if asymptotic significance value is less than 0.05 (Siegel and Castellan, 1988). Additionally, the calculation of the Chi-square value (x^2) was also conducted to test the significance because the number of ACSs evaluated in this study is larger than 7 (Siegel and Castellan, 1988). Considering that panel members have different professional backgrounds, such as government, client, contractor, consultant, and academic, Kruskal-Wallis test was conducted to examine whether any significant difference exists among the panel members of different professional backgrounds (Breslow, 1970; Hon *et al.*, 2012). The significant difference can be proved if asymptotic significance value is less than 0.05 (Breslow, 1970; Hon *et al.*, 2012).

4. RESULTS

Table 3 shows the prioritisation result of ACSs and the statistical analysis results of the two-round Delphi survey. For each ACS, the asymptotic significance value of Kruskal-Wallis test in each round is larger than 0.05, indicating no significant difference exists among the panel members of different professional backgrounds (Breslow, 1970; Hon *et al*., 2012). The asymptotic significance value of Kendall's Coefficient of Concordance test of each round is less than 0.05. The actual calculated Chi-square value (x^2) is larger than the critical value of Chi-square value in each round. These results suggest that consistency exists across the whole Delphi panel (Siegel and Castellan, 1988; Hon *et al*., 2012). In addition, the Kendall's Coefficient of Concordance of Round 2 (0.410) is larger than that of Round 1 (0.364), indicating that consistency has been improved via the two-round Delphi survey (Hon *et al*., 2012). The prioritisation of ACSs by its effectiveness is discussed in the following section.

Table 3: Results of the Two-Round Delphi Survey

Ranking	**Anti-Corruption Strategy**	**Round1**		**Round2**	
		Mean	**Asymp. Sig. of KWT***	**Mean**	**Asymp. Sig. of KWT***
1	A completed legal framework	4.29	0.996	4.36	0.996
2	Penal sanction	4.21	0.876	4.29	0.915
3	Rigorous execution of laws and rules	4.21	0.446	4.21	0.446
4	Positive leadership	3.93	0.511	4.00	0.542
4	Sound systems	3.93	0.430	4.00	0.363
6	Transparency mechanism	3.79	0.269	3.79	0.269
7	Economic sanction	3.64	0.710	3.71	0.698
8	Administrative sanction	3.64	0.538	3.64	0.538
9	Education and training	2.71	0.773	2.64	0.790
10	Raising wage level	2.14	0.269	2.07	0.354
	KCC*	0.364		0.410	
	Actual calculated Chi-square value (x^2)	45.851		51.675	
	Critical value of Chi-square from table	23.68		23.68	
	Asymp. Sig. of KCC* test	0.000		0.000	

Note: KWT* represents for Kruskal-Wallis test, KCC* represents for Kendall's Coefficient of Concordance (*W*)

5. DISCUSSIONS

A completed legal framework received the first ranking among all the ACSs. A completed legal framework plays an important role in preventing corruption because it provides the sources of provisions curbing corruption. In recent years, a series of laws, such as *The Law of Construction of People's Republic of China, and The Law of Bidding of People's Republic of China* have been legislated to curb corruption in the Chinese construction sector. Particularly, some interpretation documents of these laws are also successively issued to enhance its operability in the practical construction practice (State Council of China, 2011).

Penal sanction received the second ranking among all the ACSs. Penal sanction is the severest kind of sanction being implemented in the construction sector of China. The person that gets the penal sanction will be sentenced to prison or even to death. Thus, such kind of sanction can bring the most fear to those who may conduct corrupt practice and thus help prevent corruption.

Rigorous execution of laws and rules ranked third among all the ACSs. Although rules and regulations are crucial to address corruption issues, its rigorous execution is the guarantee of the effectiveness. Nan and Meng (2008) strengthened that even the most thorough rules and regulations will become useless without the rigorous execution. Tabish and Jha (2012) also mentioned that the rigorous execution of laws and rules can be deeply affected by the benefits networks of contracting parties which deserve more attention.

Positive leadership was ranked fourth of all ACSs. Leadership plays a vital role in preventing corruption because leaders have a strong power to establish anti-corruption measures, investigate reported corrupt practices, and decide on the punishment of verified corrupt practices (Tabish and Jha, 2012). In addition, the acts and standards of the professional ethics of leaders or those who confront the attraction of corrupt benefits can send a strong signal to their subordinates, and have a significant influence on the acts of subordinates.

Sound systems also received the fourth ranking with the same evaluation of positive leadership. A sound system has been deemed as the core component of anti-corruption strategies because it is the platform that an organisation implements its mission and vision of anti-corruption policies (Tabish and Jha, 2012). Particularly, a sound system is crucial to prevent corruption in developing countries undergoing economies transition, and it usually contains all or some of the following components: national anti-corruption program, ministerial commission, specialised agency assigned to corruption prevention, implementation program, and supervising mechanism (Tisne and Smilov, 2004).

Transparency mechanism occupied the sixth position. Sohail and Cavill (2008) observed that transparency mechanisms can provide the public with access to information on construction projects so that project performance can be monitored, and decision makers can be held accountable for their decisions. Goldie-Scot (2008) noted that some developing countries such as Tanzania, Zambia, the Philippines, and Vietnam have already made considerable efforts in introducing transparency initiatives to prevent corruption in construction.

Economic sanction and administrative sanction were ranked seventh and eighth with evaluations of 3.71 points and 3.64 points respectively. Economic sanction mainly refers to the fine imposing on corrupt organisations or individuals. Administrative sanction, such as the demotion of qualification certificates of corrupt organisations, prohibition of tendering of corrupt tenderers, and warning letters or suspension letters to corrupt individuals is also common punishment methods applied in the construction sector of China.

Education and training received the ninth ranking with an evaluation of 2.64 points. This result indicates that the effectiveness of education and training is questioned. In the construction sector of China, particularly in those public construction projects, education and training on anti-corruption issues have been conducted compulsively. But considerable efforts in current training are merely the publicity that corrupt acts should be avoided otherwise strict sanction will be incurred. Limited investment is devoted to clarify doubts on emergent ethical dilemmas, such as conflicts of interest, and gift receiving (Zou, 2006). This may be the reason why education and training got such a low evaluation.

Raising wage level was ranked last among all the ACSs. This result indicates that the Delphi panel did not consider raising the wage level as an effective anti-corruption strategy in the construction sector. National Bureau of Statistics of China (2012) revealed that the wage level in the construction sector of China ranks 6th among all the 19 sectors which also suggests a not too low wage level in the sector. Additionally, Zhou and Liu (2004) stated that the high wage level could not help prevent corruption if the potential corruptor is risk loving. Long and Tian (2008) also opined that the effect of the high wage level in corruption prevention is doubted in developing countries undergoing economic transition where numerous opportunities exist for potential corruptors to grab corrupt money.

6. CONCLUSIONS

This paper has conducted a two-round Delphi survey with 14 industry experts and academics to evaluate the various anti-corruption strategies being implemented in the construction sector of China. Results show that the most important anti-corruption strategy is a completed legal framework, followed by penal sanction, rigorous execution of laws and rules, positive leadership, sound systems, transparency mechanism, economic sanction, and administrative sanction. Education and training, and raising the wage level, on the other hand, were perceived as least effective, according to the Delphi experts. This paper provides a clear picture of ACSs in the construction sector of China and evaluates the effectiveness of these ACSs.

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APPLICABILITY OF EARNED VALUE MANAGEMENT AS A PERFORMANCE MEASUREMENT TOOL FOR SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

This study is based on the Earned Value Management (EVM) performance measurement technique and its practice in Sri Lankan construction industry. Since the project success clearly depend on accuracy on evaluated performance measurement, EVM have emerged through various techniques, due to its higher degree of reliability, effectiveness, accuracy, and efficiency.

Data collection was done through the case study research approach and cross case analysis was used for data analysis. Four cases were selected to extract the current practice of EVM and its suitability as a performance measurement for the industry.

In traditional methods, physical progress is not taken into account when analysing cost performance. Instead, actual cost of a project up to date is simply compared to planned costs, often with misleading results. Therefore, as a mitigating measure, EVM can be applied for measuring a project's performance forecasting future trends and analysing variances in the schedule and budget as the project proceeds. EVM as a standard method can be considered more successful with better results in projects simple and direct with a detailed scope. As evidenced in the case study, projects with complex and incomplete final products show higher deviations in the use of the technique. The EVM suggests a cultural change in the process of projects control; therefore people who have experience in dealing with the tool are really necessary in this process. The way an organisation implements the tool, influences directly to the results. If it had an organisational support, provided by specialised resources, will have better results in terms of application.

Keywords: *Construction; Earned Value Management; Performance Measurement; Sri Lanka; Traditional Methods.*

1. INTRODUCTION

Criteria of construction project's success has constantly enriched in project management context. Therefore, a systematic critique of the existing literature is needed to develop framework for measuring construction success both quantitatively and qualitatively (Chan and Chan, 2004). Thus, the performance of a construction project has been judging using different traditional approaches to get a better picture of the project's status (Khamidi *et al.*, 2011a). Therefore, as a new performance measurement technique, EVM has been originally developed by the United States Air Force and it has increasingly being addressed in the literature of project management over the years. Since, there was a lack of literature on EVM in Sri Lankan context this article examined the emphasis of practicing the EVM methodology in Sri Lankan context and its conceptual underpinnings and applicability as a measuring process of a project's performance, based on the particular benefits and drawbacks comparing to traditional approaches.

2. PROJECT PERFORMANCE MEASUREMENT

Before any construction project becomes a project, it begins as a concept which is subjected to evaluation at some high level of management (Nalewaik and Witt, 2010). Further, Bokhary (2010) indicated that to make that concept reality the project must comprise with temporary set of activities which had planned from the beginning to ensure the timely completion with desired quality and budget. Since, construction

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industry is usually famous for its underperformance, due to several uncertainties in the system; project duration is not expected to be exact like any other output of a project (Kagioglou *et al.,* 2001). Therefore, it is necessary to introduce a system for project scheduling and monitoring into the project management. Hence, Project scheduling began in order to mathematically scheduled the planned activities, while act as a predictive model for performance measurement of the project (Vanhoucke, 2012).

Many researchers had introduced several performance measuring techniques, which can be separated according to three levels in project management, i.e. project level, organisational level and stakeholder level. According to Lin and Shen (2007), it is important to carry out performance measurement at organisational level considering not only financial aspects but also on non-financial aspects such as time and quality of work and Wang and Huang (2006), further stated that measuring the owner's, the supervisor's and the contractor's performances are significantly related to the criteria of project success. Mostly there are researches conducted in project level and there are several Changing measures of project performance over the last 10 years. Meantime, a study conducted by Lin and Shen (2007), had found that the 68% of total number of researches in performance measurement had conducted at the project level.

A study by Yang *et al*. (2010) indicated the main purpose of performance measurement is to measure and improve the efficiency and the quality of the performance, and identify opportunities for progressive improvements in performance using both traditional and new philosophies. Kagioglou *et al*. (2001) and Khamidi *et al.* (2011a) had found several traditional approaches such as day to day monitoring, monthly or weekly management reports, performance reviews, key performance indicators, 'S' curves and financial management techniques and new techniques such as EVM and Schedule Risk Analysis to measure the project's performance continuously throughout the project life time.

In performance evaluation, main considerations are time, cost and quality; therefore it is important to use mechanisms which can measure both factors simultaneously. One of those mechanisms that monitor both dimensions is time-cost analysis, which is monitor the project's progress as a function of the cumulative costs and plotted against time for both budgeted and actual amounts (Bokhary, 2010). Other than above mentioned techniques Gantt charts, control charts, and milestones are often used to monitor project performance. However, as mentioned by Bokhary (2010) these tools track progress only in the dimension of time while, other important dimension of project performance, cost, is virtually ignoring. This disadvantage created significant problems for several high profile US aircraft development projects in the early 1960s, and ultimately led to the adoption of the more popular analytical approach of EVM. Next explains the EVM in detail.

3. BACKGROUND OF EVM

Anbari (2003), Fleming and Koppelman (2010) has explained the EVM and its applicability as a performance measurement technique for construction industry. Further, as per a study conducted by Nagrecha (2002), earned value is an enhancement over traditional accounting progress measures and goes one step further and examines actual accomplishment. According to study conducted by Czarnigowska (2008), EVM had proved its usefulness in practice of cost control by establishing the current status of a project while predicting its likely final effect, using its cost and schedule information from project's Work Breakdown Structure (WBS), project network and the schedule. Further, Pajares and Paredes (2011) has illustrated that, EVM use new real data generated during project run time to forecast the trends for the future project total cost and finishing date (based on past performance). Thus, many researchers have recognised the importance of EVM in creating an early and accurate image of the status of a project for performance evaluation and project management.

A study in Korean construction industry conducted by Kwon *et al.* (2008) found out that the application of the EVM can be considered more successful in projects which have clear and tangible objectives, with a detailed scope, simple and direct. Vargas (2003) argued that applicability of EVM analysis will be widely enlarged, if the data collection is made in adequate speed and accuracy and the information is correctly compiled accomplishing the deadlines and if it fails EVM will not add much effect to the process of project control. However, Kwon *et al.* (2008) had argued in a study, that incomplete projects or projects that involve aspects of creativity, which make a precise plan impossible, show high in viability in the use of the technique. Therefore, to minimise the misuse of EVM and maintain its quality, there are several established standards such as ANSI/EIA standard 748-A guidelines published by National Defence Industrial Association (NDIA) in USA, AS4817 published by Australian standards committee and PMI practice standards by the Project Management Institute (PMI) to establish the requirements and to get a fundamental understanding of the principles of EVM and its role in facilitating effective project management.

4. EVM TERMINOLOGY

Currently practicing standard EVM terminology for the calculations for EVM was first devised by the US Department of Defence in 1996 comprising with dozens of acronyms numbers. However, regardless of the kind of project (construction, production, defence, and space), only three basic data elements, Budgeted Cost of Work Scheduled (BCWS), Budgeted Cost of Work Performed (BCWP), and Actual Cost of Work Performed (ACWP) are central to proper planning, measurement, and analysis of data (Christensen, 1998). Nearly all of the other data items, project status indicators, and earned value "forecasting" parameters have been derived from them. Cost Variance (CV), Schedule Variance (SV), Cost Performance Index (CPI) and Schedule Performance Index (SPI) indicate the current performance of the project. Vanhoucke and Vandevoorde (2006) concluded that CPI and SPI provide valuable information about trends in project performance and Warburton (2011) further stated that, when implementing corrective managerial actions, the changes in the behaviour of the indexes are assumed to reflect the impact of management actions as illustrated in Table 1.

Table 1: Schedule and Cost Performance from CV, SV, SPI and CPI

Project Status Indicators Variances	**Positive**	**Zero Value**	**Negative**
Cost Variance (CV)	Cost overrun	On budget	Cost under run
Schedule Variance (SV)	Behind schedule	On schedule	Ahead of schedule
Indexes	**Greater than 1**	**1**	**Less than 1**
Cost Performance Index (CPI)	Cost overrun	On budget	Cost under run
Schedule Performance Index (SPI)	Behind schedule	On schedule	Ahead of schedule

Source: Adapted from Kim *et al*. (2010) and Pajares and Paredes (2011)

To Complete Performance Index (TCPI) and Estimate at Completion are the forecasting parameters of the project. If the project is delayed or over-budgeted, can use TCPI to determine the project performance required to complete the project as budgeted or estimated. TCPI also leverages the EVM formula (Sharma, 2009).

5. EVM PRACTICE IN SRI LANKA

Traditional methods and EVM have been used in worldwide for performance measurement of construction projects in last three decades. Most of the countries in the world, especially USA had introduced EVM as a standard for the construction projects, and currently investigate for its newest improvements, since EVM had proved its usefulness in practice of cost control by establishing the current status of a project while predicting its likely final effect, using its cost and schedule information from project's WBS, project network and the schedule (Czarnigowska, 2008). While Korean Construction Industry applied it to most large-scale constructions for achieve a successful outcome, in Australia, it has use for add value to the effective commercial project management under Australian EVM standards (Kwon *et al*., 2008). However, unfortunately in Sri Lankan context EVM had not gained any attention or importance. Hence, there is not an established standard for project performance evaluation in Sri Lanka, the success or failure of a project depends on traditional methods which had many disadvantages comparing to EVM. Therefore, it indicated that the necessity of applying EVM in the Sri Lankan construction industry had significantly enlarging its important, using its arrogant advantages and history of success.

6. RESEARCH METHODOLOGY

To study the application of EVM as a performance measurement it is necessary to compare the benefits and the limitations arose during the practice of the technique with other traditional methods of measurements in Sri Lankan Context. Therefore, the study was conducted as a cross case analysis using four number of construction projects from both EVM practice and traditional approaches., interviews were adopted as the data collection technique as the most reachable and reasonable data collection tool when considering circumstances and the nature of the research and the restrictions on accessibility to other sources of data. Since, in semi-structured interview, the interviewers seek for clarification and elaboration on the answers given where the interview is balanced between free-flow and directed conversation, semi-structured interview was selected as the data collection tool. According to Senarathne (2005), code-based content analysis enables to find similar cognitions under a particular concept and consider its significance rather than the actual content of the segment. Therefore, code-based content analysis was used in this study to capture significant findings from the transcripts and for effective interpretation of those.

7. RESEARCH FINDINGS

Cross case analysis has been carried out to identify the similarities and differences between each case, on the way to find out; the current practice of performance measurement techniques, benefits and issues arose in the implementation of the EVM and other traditional methods and applicability of EVM as a suitable measure for project performance measurement and progress monitoring.

Performance measurement techniques in current practice

According to research findings, there are only limited numbers of companies which practice a particular technique for performance measurement such as EVM or cost coding systems in Sri Lanka. Those companies has selected, because it required to compare the project's status with the cost base line and schedule base line and then forecasting the trend of the project in terms of cost and time, which can be only done using EVM. Other than those companies others were using traditional approaches such as, "S" curve, Gantt charts, management reports and the audit reports of the project and performance reviews for the project management.

7.1. BENEFITS AND LIMITATIONS IN PERFORMANCE MEASUREMENT PRACTICE

Table 2: Comparison of the Practice of Measurement Techniques

Requirement of the respondents	Traditional method	EVM
Technique which is simple	Simple	Not simple
Able to maintain with limited staff	Give unbearable working load for the person who give progress reports	With the systematic method require person who has authority to collect required data
Less initial cost	initial cost was less, since only general software were required, and able to manually conduct the process	Initial cost is high since the method requires particular software and hardware to build up the system.
Easy to maintain	Not easy to maintain, had to do calculations repetitively for every report.	Easy to update and maintain since the system is already build up
Limited technical knowledge	Did not require any technical knowledge	Require knowledge to control particular software for updating process

Requirement of the respondents	Traditional method	EVM
Higher accuracy of data	Less accuracy of data since, process was manually conducted	Higher accuracy of data, since systematic approach used
Capable to measure actual progress of the project	Actual progress is unable to measure	Measure Earned value of the project
Measure required performance for timely completion	Cannot measure required performance	Measure To Complete Performance Index (TCPI)
possibility to forecast the time for completion and probable final cost	Use experience to predict the probable situations	Measure Estimate At Completion (EAC) in for both time and cost

As shown in Table 2, as plus points of traditional methods, it was easy to practice those methods, "S" curves, Gantt charts, progress reports and management reports, because they are easy to generate, update and simple to understand and EVM was more complex and require more resource persons and software and hardware to administrate the project. However, traditional methods were easier to evaluate the performance of the projects it cannot estimate the actual performance level and the required performance for timely completion of the project which can be clearly measure with EVM technique by developing the cost loaded base line schedule for the project and updating it constantly.

Projects which had use traditional approaches has faced difficulties when comparing the planned work with actual cost of the project, since actual cost did not specified what had been completed and only mentioned the total expenditure of the project for particular period. Therefore, the readings misconstrued the status of the project which leads for erroneous decisions when administrating the project. While, EVM allocate resources for particular tasks separately and measure the planned work and the actual work done using those data and avoid the errors which may happen in present project status and the future project forecast by using the actual value of the work completed for the calculations.

Moreover, when using traditional approaches, progress monitoring of a project also had to repeat with the time and repeating same format of calculations were difficult to continue throughout the project life, while the calculations for variances and indices and forecasting the trend in EVM technique were not difficult to continue after preparation of the cost loaded base line schedule for the project.

EVM had provide very convenient data using TCPI, which shows the value of cost performance index that is to be maintained from now on if the project is to be completed to budget and SV and CV variances and SPI and CPI indices, which provide valuable information about trends in project performance. While traditional approaches had not provide a clear quantitative picture of the true project status and further it does not provide a means for extrapolating project cost to complete or completion date.

The main issue arose in practicing EVM in Sri Lankan context is the difficulty in reporting earned value due to several reasons. First getting actual costs onto each task is difficult, setting up an automatic interface between departmental databases and project management systems are not trivial and usually projects do not use a standard formats and data bases and using the earned value mechanism in these systems are typically not straightforward and simple. Therefore, when implementing EVM in a project, it required an experienced contractor who has standard formats and databases for data reporting and monitoring to maintain the reliability and accuracy of the data used for the process. Further, Earned Value reporting cannot be handled in an easily implemented manner and required professional service for implementation. However, since limited resources were available, it was difficult to give much time or support for performance measurement process. Therefore, to use EVM method efficiently, it requires a disciplined approach to collection of data on project cost and progress and the findings are to be processed immediately. The purpose is to detect any deviation as soon as possible, so that there is enough time to asses if the deviation is dangerous for the project and, if necessary, to take corrective actions. Therefore, collect data within the time is important or had to invent another solution for the time problem.

Further, findings indicated that in both practices, due to limited financial support for the project monitoring process, lack of staff for progress monitoring and controlling had create conflicts in responsibilities since, there was not any particular person assigned to measure performance and progress monitoring. This situation had lowered their liability of the data and delay the data collection and evaluation process which finally reduced the accuracy of the conclusion.

Minimum awareness of EVM and lack of experts in the industry had had create less interest to use EVM in the industry. Cost for the software and hardware which required for the measuring process of EVM technique are too costly and it required lots of technical knowledge in the beginning to administrated these software and hardware and maintain afterwards. Therefore, it required lot of effort to change the people in to the system and introduce EVM.

8. CONCLUSIONS

When concluding research findings, it can be stated that, in the initial stage traditional performance measurement is simple and easy to apply to a project and easy to understand. However, during the constructions develop the schedules and measure the performance time to time was not an easy task. The findings had described that, the requirement for systematic method for performance measurement had been identified through limitations of traditional methods. Further, it had identify that, most of the people in the industry, without a clear idea about the EVM, think it as a time wasting and costly technique while, using EVM to measure performance during the progress was not difficult and actual limitation is the higher cost and time requirement in initial stage of EVM practice.

As a plus point of traditional methods that, it does not require any special software or hardware which cost more for the process since, it can be manually proceed without usually available software such as Microsoft Excel or word. However, it was also agreed that, it did not calculate the work done in depth and the accuracy of the result was less since it cannot verify the reliability of data. Therefore, according to the cross case analysis and other empirical data, accuracy of the data get the priority and requirement of proper system to update data continuously had been initialised. Other than that, as a limitation of EVM the respondent had identified the additional cost requirement for the software, hard ware and technical knowledge in the beginning to administrate the process which unable to overcome since, accuracy of the data was depending on the reliability of the system.

As other limitations of traditional methods are, they demonstrate that, traditional methods were unable to estimate about what will be the total cost and the duration in the completion other than a prediction according to the experience and practical knowledge. Thus, in EVM it is able to measure the EAC on both cost and time. Since, performance evaluation reports were used for decision making of the project; it will be suitable to use a system which can measure the probable time duration for the project and the probable cost. Other than that, performance measurement had been demonstrated as the heart of the project management, measures and the parameters had achieved a level that get highest priority of the project. Therefore, empirical data had demonstrated several plus and minus points of two types of performance measurement techniques implemented on project management (Refer Table 2). Since traditional methods which practicing currently had several limitations which can be mitigate by using EVM in Sri Lankan Construction Industry, it can be concluded that practicing EVM in Sri Lankan context will improve the accuracy and the reliability of the project performance measurements and it is the most effective technique for the project performance evaluation process.

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APPLICABILITY OF RELIABILITY CENTERED MAINTENANCE APPROACH FOR THERMAL POWER PLANTS IN SRI LANKA

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ABSTRACT

More than 70% of entire power demand in Sri Lanka mainly caters through thermal power and oil base thermal power plants contributes to cater more than 55% of demand in the country. Even though plant reliability and efficiency should be maintained at higher value to cater this demand, sudden island wide power cuts and Ceylon electricity board (CEB) statistics has been revealed the prevailing plant performance issues of thermal power plants.

Reliability Centered Maintenance (RCM) approach has been adopted successfully for wide range of industries including thermal power industry in considerable number of countries to overcome plant performance issues while reducing maintenance cost. Therefore the focus of this research is to study applicability of RCM approach for maintenance planning of thermal power plants in Sri Lanka to overcome current issues relating to maintenance operation. Comprehensive literature review was conducted to explore RCM concept. Through the preliminary survey current maintenance practices, issues that directly related with maintenance practice, currently available resources that necessary for RCM base analysis and attitude of industry practitioner towards RCM implementation were identified. Streamline Reliability Centered Maintenance (SRCM) was identified as ideal type of RCM analysis method for thermal power plants in Sri Lanka through findings of literature review and preliminary survey.

Findings of single case study revealed criticality evaluation criteria and applicable maintenance strategies for critical and non-critical components of typical thermal power plants. A comprehensive maintenance plan was developed for fuel pre pressure system using currently available physical and human resources. Considering findings, the research suggests that thermal power industry in Sri Lanka should initiate SRCM base maintenance program to overcome existing performance issues using existing resources.

***Keywords**: Maintenance Optimisation; Performance Issues; Reliability Centered Maintenance; Thermal Power Plants.*

1. INTRODUCTION

Drawing parallels to many emerging economies in the world, Sri Lanka has been grappling to meet the rising demand for power (Illangasekera and Jawfer, 2012). Public Utilities Commission (2013) reveals maximum recorded electricity demand in Sri Lanka was 2146.4MW in year 2012 and in order to cater existing power demand installed capacity of Sri Lankan power plant is 3323 MW. According to Ceylon Electricity Board (CEB, 2012) install capacities of hydro and thermal power plants are 1584 MW and 1638 MW respectively.

Sri Lanka's thermal power system comprises both Ceylon Electricity Board (CEB) and Independent Power Producers (IPP) owned power plants operated with auto diesel or fuel oil (Ratnasiri, 2013). According to Ceylon Electricity Board (2012) 71% of total electricity demand was catered through thermal power plants. Further Oil base thermal power plants and existing coal based thermal power plants have contributed by 59% and 12% respectively to provide entire power demand.

Ministry of Power and Energy (2012) reveals that island wide two hour power cut experience due to a sudden breakdown at the Kerawalapitiya West Coast Thermal Power Plant and the Lakwijaya Power Plant in Puttlam. The CEB had to face a power crisis as they are deprived of 400 MW of power, due to the breakdown. Further CEB (2012) reveals that several CEB own thermal power plants have been operated at

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low thermal efficiency. In order to successfully compete in the electrical generating industry today, plant availability and reliability must be maintained at desired levels while operating costs must be kept as low as reasonably achievable (EPRI, 2001).

The availability of a complex system like thermal power plant is strongly associated with the parts reliability and maintenance policy (Carazas, and Souza, 2010). In general, it is viewed from the perspective of maintenance policies such as Corrective or breakdown Maintenance (CM), Preventive Maintenance (PM), and Predictive Maintenance (PDM). Sometimes, maintenance concepts like Total Productive Maintenance (TPM) or Reliability-Centered Maintenance (RCM) are also included in the above list (Pinjala *et al*., 2006).

Nowlan and Heap (as cited in Fore and Mudavanhu, 2011) RCM is defined as "a structured process for developing or optimising the maintenance requirements of a physical resource in its operating context to realise its inherent reliability by logically incorporating the optimal mix of reactive, preventive, condition-based and proactive maintenance practices". The goal of this approach is to reduce the Life-Cycle Cost (LCC) of a facility to a minimum while continuing to allow the facility to function as intended with required reliability and availability (National Aeronautics and Space Administration [NASA], 2008).

The aim of this research is to study applicability of RCM approach for maintenance planning of thermal power plants in Sri Lanka. In order to achieve this aim first a thorough literature review has been carried out to identify the current issues of thermal power plants relating to maintenance practices and different maintenance strategies used. Then availability of resources that required for RCM implementation initiative and barriers to implement RCM approach were evaluated. After identifying applicable type of RCM analysis for thermal power plants in Sri Lanka, applicability of selected type of RCM analysis method was evaluated.

2. RELIABILITY CENTERED MAINTENANCE

RCM has been widely recognised by maintenance professionals as the most cost effective way to develop world class maintenance strategies by determining what must be done systematically and scientifically to ensure that physical assets' continues operation in order to fulfil user requirements. RCM leads to rapid, sustained and substantial improvements in plant availability and reliability, product quality, safety and environmental integrity (Moubray, 1992).

Literature reveals different types of approaches for RCM implementation. These approaches are called classical, rigorous, intuitive, streamlined, or abbreviated (Pride, 2008). Rigorous RCM requires too many resources to perform an analysis on an average system. Streamlined Reliability Centered Maintenance (SRCM) has been developed to overcome this issue. The SRCM process has been validated against rigorous RCM by applying both methods independently on same plant. According to comparison of the result obtained through both analyses had slid difference (EPRIGN Engineering and Research, 1999).

Only the important functions are evaluated in the critical analysis in the streamlined RCM Process. If the component is determined to be critical, the analyst identifies the appropriate failure causes and recommends the applicable PM tasks to prevent or detect the identified failures. Components that are initially analysed in the Critical Analysis but are identified as non-critical will get evaluated again during the Non-critical analysis to determine if there are cost effective PM tasks that should be performed (EPRI, 1998, 2001). EPRI (1998, 2001) stated that non-critical analysis provides an evaluation using economic criteria for those components that were identified as functionally non-critical in the Critical Analysis.

The next step is to recommend applicable and effective preventive maintenance tasks based on the component's importance. Selecting the type of task to be performed and the frequency of the task can be accomplished considering the analyst selects failure causes associated with failure modes and effects. Another method available to determine the appropriate preventive maintenance tasks for each component is the standard RCM logic tree analysis (EPRI, 1998, 2001). The final step of SRCM analysis is recommendations with the existing PM program for revise the recommendation (EPRI, 1998).

3. RESEARCH METHODOLOGY

This paper basically focuses on how RCM approach can be applied for maintenance planning of thermal power plants in Sri Lanka to overcome current issues relating to maintenance operation. A mix approach including survey and case study was used to accomplish aim and objectives of the research.

A preliminary survey was conducted with expert industry practitioners in order to identify current maintenance practices, current issues directly related with maintenance operations, available resources and practices that support to RCM implementation, attitude of practitioners for RCM implementation and barriers of RCM implementation in Sri Lankan thermal power industry. Findings of comprehensive literature review were used to identify types of RCM approaches and criteria to be considered to determine appropriate type of RCM approach. Comparing findings of preliminary survey with circumstances that each type of RCM analysis method applied, SRCM approach was chosen as most appropriate RCM approach for thermal power plants in Sri Lanka. Preliminary survey was limited to seven thermal power plants that represent 71 percent of installed capacity of thermal power sector.

A single case study was conducted using a selected typical case to identify the applicability of RCM based approach for maintenance planning of thermal power plants to overcome current issues relating to maintenance operation. Semi structured interviews were used as the data collection technique for the preliminary study. Further semi structure interviews, documents, archival records, direct observation were used as data collection techniques for the single case study.

Simple statistical parameters such as mean, mode, percentage were used as data analysis techniques for preliminary survey. Further content analysis and SRCM analysis process were used as data analysis techniques for single case study to develop comprehensive maintenance plan for most important system that affect the plant operation. Development of maintenance plan limited to most important one system for plant operation.

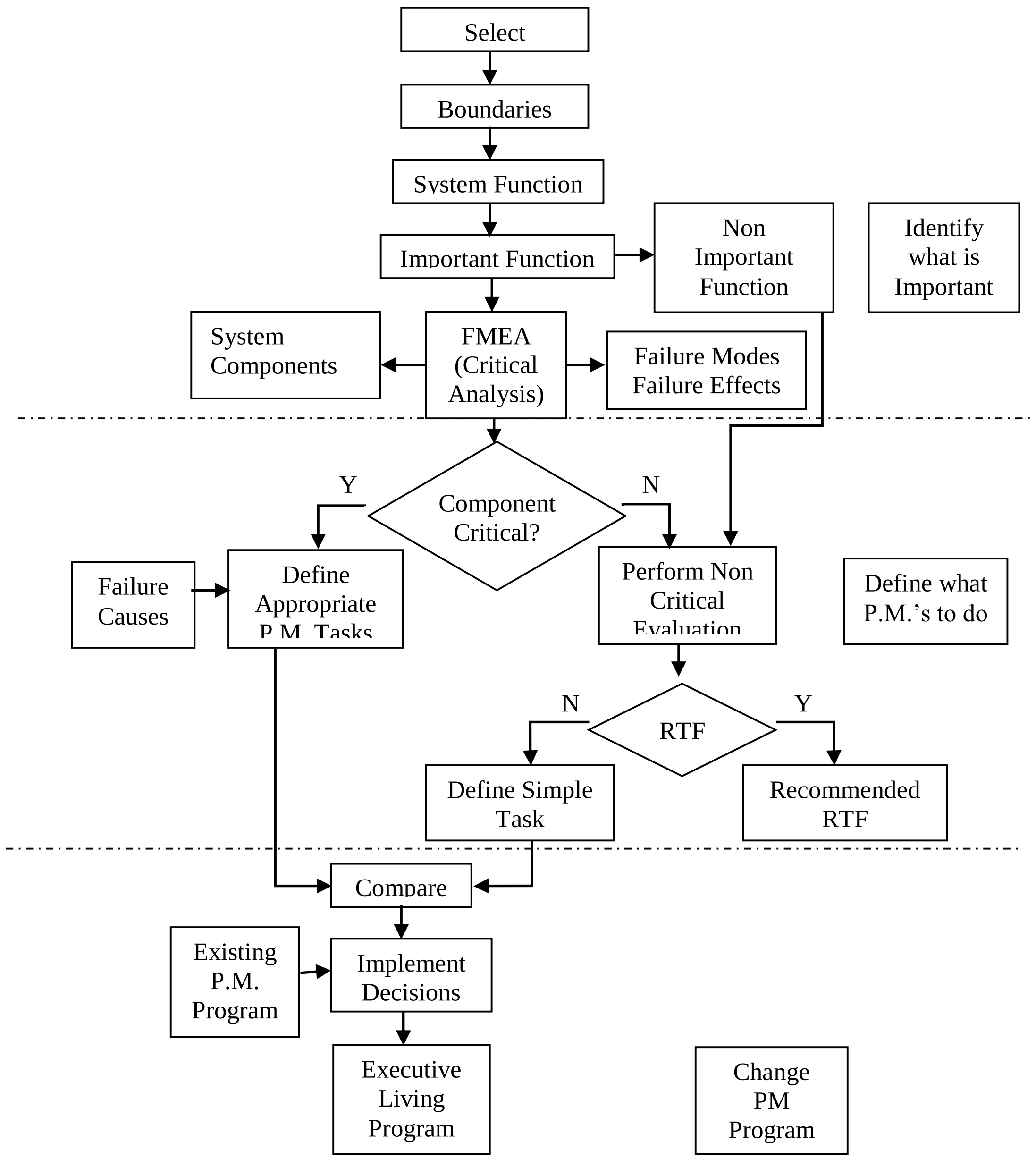

Figure 1: SRCM Analysis Process
Source: EPRIGN

4. RESEARCH FINDING AND ANALYSIS

4.1. FINDINGS OF THE PRELIMINARY SURVEY

Table1: Plant Capacity

Plant Code	Capacity (MW)
A	168.5
B	300
C	165
D	215
E	160
F	24
G	100

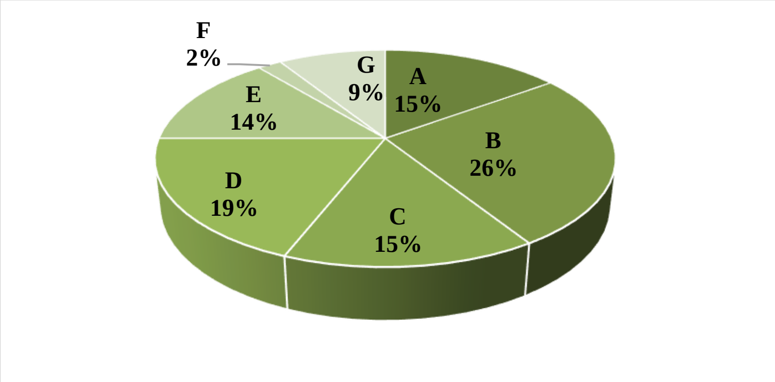

Figure 2: Capacity Profile

Overall capacity of selected thermal power plants for this preliminary survey is 1132.5 MW. Therefore these selected power plants represent 71.31 % of total thermal power sector in Sri Lanka. Further according to responses obtained through preliminary survey, preventive maintenance is the most widely adopted maintenance strategy for thermal power plants in Sri Lanka.

According to Table 2, the main factor affecting to the current maintenance related decisions is manufacture recommendation. The next important factor according to the priority is ensuring power generation reliability.

Table 2: Factors Affecting to Current Mix of Maintenance Strategy

Factors Affecting for Current Mix of Maintenance	Percentage of Power Plant the Factor has been Affected	Priority Order
Traditional practice	14%	6
Manufacturer recommendation	100%	1
Legal requirement	29%	5
Maintenance budget	14%	6
Safety and environment issues	57%	3
Energy efficiency	43%	4
Ensuring power generation reliability	86%	2

According to findings, 71.43% of power plants used for preliminary survey have been confronting reliability and plant availability issues. The next most commonly faced issue according to priority order is plant efficiency related issues, which affected to 57.14 %of power plants used for this study. 42.86% of the power plants have faced safety issues and environment related issues according to opinion of the respondents.

Fortytwo percent (42%) of professionals are aware regarding RCM concept and 57 % of professionals are not aware regarding RCM concept. Further, all the seven number of expert professionals contributed to preliminary study accepted the necessity of using analysis method for rational decision making regarding power plant maintenance.

5. Application of Streamline Reliability Centered Maintenance for the Selected Case

The thermal power plant labelled as G in the preliminary survey was selected for in detail single case study regarding applicability of SRCM approach. This selected power plant has been categorised as Internal Combustion (IC) engine base power plant. The main fuel type used for operation is Heavy Fuel Oil (HFO). At the moment all the maintenance operations are conducted by in house maintenance staff. Maintenance tasks and respective frequencies have been decided mainly depending on manufacture recommendation and past experience of failures.

According findings, prevailing main issues affecting the plant operation are plant reliability related issues and plant efficiency related issues. Budgetary issues, safety related issues, environmental Issues and contractual issues are not critical for plant operation.

According to literature, basic required resources that should be available in facility in order to successful implementation of SRCM approach are as follows.

- System descriptions and system drawings
- Component list
- Component corrective maintenance history for 3- 5 years
- Existing preventive maintenance plan
- Plant professional with expert knowledge to analyse the systems

According to findings it can be concluded that there are sufficient basic resources within the selected case in order to initiate SRCM based maintenance practices.

Through semi structured interviews all the steps associate with SRCM analysis process were identified as feasible steps in selected power plant. Those feasible steps are as follows.

- Ability to failure mood determination of component
- Ability to failure effect determination of component
- Ability to determine component criticality under criticality evaluation criteria
- Ability of failure cause determination of components
- Ability of optimum maintenance tasks selection for critical component
- Ability of maintenance task selection for non-critical components

Main fuel system was identified as most important system according to results obtained through evaluation of importance of main system of power plant facility. There were fourteen identical generator units with 7.1 MW power generation capacities to provide 100MW total capacity of power plant. Each generator unit has separate auxiliary systems. However fourteen number of generator units depends on common starting compressors and main fuel supply system. Therefore, main fuel supply system was selected as the most important system of power plant considering importance on entire power generation process and expert views of maintenance professionals.

Main fuel supply system consists with main HFO unloading tanks, HFO separators, HFO service tanks, diesel tanks and fuel pre pressure unit. There are three number of fuel separators and two separators are sufficient to provide required fuel amount for full load operation of power plant. One pre pressure unit is sufficient only for providing required fuel amount for any seven number of generator units for their full load operation. Therefore, operation of both units is very important to operate entire plant with fourteen generator unit at full load capacity. Thus, reliability of power generation process totally depends on reliability of two identical pre pressure units. Considering this importance one pre pressure unit of two identical units is considered to develop optimum maintenance plan using SRCM approach.

One pre pressure unit basically consists with diesel supply pump arrangement, HFO supply pump arrangements and auto filter. Diesel supply pump arrangement consists mainly with a strainer, a motor driven pump, non-return valves, a pressure valve and Globe valves. HFO supply pump arrangement consist two identical arrangements consisting of a strainer, a motor driven pump and non-return valves. There is a pressure valve to regulate the pressure in HFO system. Further pressure release safety valve has been integrated with HFO supply arrangement that consisting heated up HFO to ensure the safety of the system. An auto filter has been integrated next to the pre pressure pump arrangement to improve quality of HFO through filtration process.

HFO supply pipe line and diesel supply pipe line has been interconnected before pre pressure pump arrangement through three way valve to convert HFO supply pump arrangement in to diesel before maintenance operation of HFO supply pump arrangement as a cleaning method. Further this arrangement is very important to convert HFO supply system into Diesel prior to long-term shutdown of plant.

5.1. *FUNCTION/ FUNCTIONAL FAILURE ANALYSIS (FFA)*

Table 3: Function/ Functional Failure Analysis
System: Fuel Pre Pressure System

ID	Function	Functional Failure
01	Supplying required Fuel amount for Generator Facility.	Fails to provide required fuel amount for Generator Facility
02	Maintain the quality of Heavy Fuel Oil (HFO) with filtration process.	Unable to maintain required quality of HFO

5.2. *FAILURE MOOD EFFECT AND CRITICALITY ANALYSIS*

Table 4: Criticality Analysis Report

Component ID	Failure Modes	Failure Effect	Critical?	Criticality Evaluation Criteria	Failure Causes
DV 0008/ 0010/ 0011/0012 - Diesel pre pressure unit Globe Valve	Fails to close Fails to open Oil leaks	Difficulties for maintenance Operation Operator action required	No	Component is important to support maintenance or operation activities	Corrosion Valve Gland failure
DP 0002 – Diesel Oil pre pressure pump	Fails to start Fails to run (Include degraded operation)	Loss of redundancy Unable to provide required Fuel requirement for Generators	Yes	Result in reduction of significant power generation capacity of plant	Electrical failures Bearing damage Damage of coupling Mechanical oil seal damage

5.3. *MAINTENANCE TASK SELECTION*

Table 5: Maintenance Task Selection for Critical and Non Critical Components

Component ID	Component Type	Recommended Task	Interval	Resp. Discipline	Recommended Base	Critical?
DV 0008/ 0010/ 0011/ 0012 - Diesel pre pressure unit Globe valve	GV - Glob Valve	Check for the operation and oil leaks Clean and Lubricate the valve	1M	MTC	This decision has been made based on Staff interview	No
DF 0002 – Diesel oil pre pressure pump Strainer	STR – Strainer	Check the suction and discharge pressure of pre pressure pump and Clean the strainer	2W	MTC	This decision has been made based on Staff interview	YES

5.4. COMPARISON OF EXISTING AND RECOMMENDED MAINTENANCE TASKS

Table 6: Comparison of Existing and Recommended Maintenance Tasks

Component ID	Existing Task	Interval	Recommended Task	Interval
DV 0008/ 0010/ 0011/ 0012 - Diesel pre pressure unit Globe valve	Run to fail		Check for the operation and oil leaks Clean and Lubricate the valve	1M 1M
DP 0002 – Diesel Oil pre pressure pump	Replace oil seal Bearing Replace	1Y 2Y	Replace oil seal Bearing Replace Perform Vibration Analysis Perform Motor Current analysis	1Y 2Y 6M 6M

Criticality analysis report presents criticality analysis results regarding each and every component of pre pressure unit under their operating context. Through this analysis each and every component identified consist of pre pressure system has been evaluated according to their operating context. Analysis reveals that same component under different operating context and different systems, has different level of criticality for entire plant operation. As an example the normally closed glob valve holding component ID HV0027 is a critical component for plant operation under its operating context even though other most of the globe valves in system are not critical. Therefore each and every component at the system should be evaluated to identify whether the component is critical under criticality evaluation criteria prior to assign maintenance task. Failure mood and failure effect identification helps to evaluate the criticality of component under criticality evaluation criteria. Further identified causes for each failure mood which is important to maintenance task selection also has been presented in criticality evaluation report.

Critical and non-critical task selection summary report has been presented recommended maintenance task for each and every component of the pre pressure unit assigned under critical task selection process or non-critical evaluation process. Maintenance task selection was done under critical task selection process for components decided as critical under criticality analysis. Further maintenance task selection was done under non critical evaluation process for component decided as non-critical through criticality analysis process. Required condition monitoring or condition based maintenance task, time based preventive maintenance task and surveillance task have been assigned for critical components according to requirement under critical task selection. Only time based preventive maintenance task and surveillance tasks have been assigned under non critical evaluation process according to requirements. Any non-critical components that any maintenance task has not been assigned and allowed to run to fail have not been compatible with non-critical evaluation criteria.

Recommended maintenance task and their intervals were compared with existing maintenance program through task comparison table. Through this process modification for recommendation can be done prior to implement. According to this analysis it is obvious that additional maintenance tasks were added with compared to existing maintenance practice considering the criticality of components as mentioned in the comparison report. Further through this analysis several neglected component have been identified as critical components. As an example, annul operation test has been recommended for pressure release safety valve of HFO system. This comparison report further reveals that applicability of currently available predictive testing techniques with power plant such as thermography, vibration analysis for critical component to improve the reliability and safety. The examples are inspection of HFO line for fuel leaks with thermography, application of vibration analysis and motor current analysis for fuel pumps.

6. CONCLUSIONS

The preliminary survey disclosed current maintenance practices, existing issues, available resources and practices that support the RCM implementation, attitude of practitioners for RCM implementation and barriers of RCM implementation considering the profile of power plants used for preliminary survey in Sri Lankan thermal power industry. Single case study findings have been presented including existing issues of selected case, evaluation of applicability of SRCM process for selected case, applicability of each step of SRCM process together with applicable evaluation criteria and applicable type of maintenance strategies. Further developed SRCM based maintenance plan for selected case has been presented.

6.1. RECOMMENDATIONS FOR INDUSTRY PRACTITIONERS

The prime objective of application of RCM base approached for various industries is to minimise the cost associated with maintenance operation while reliability of plant and equipment is increased. According to research finding more than 50% of practitioners of thermal power industry which is reliability is concerned are not aware about the RCM concept. Therefore knowledge regarding new maintenance concepts of industry practitioners should be improved through training programs and continual professional development program. According to findings of this research there are sufficient resources to initiate SRCM base maintenance program. Therefore following recommendations are suggested for industry practitioners.

- Try to implement SRCM base maintenance program as pilot study for a problematic history and evaluate the success as initiation to RCM base maintenance program in Sri Lankan context.
- Use corrective maintenance records to determine optimum maintenance interval of components.
- Get consultancy services to obtain expert knowledge to establish RCM base maintenance program.
- Always try to obtain information regarding expected lifetime of component to determine preventive maintenance interval

6.2. RECOMMENDATION FOR ACADEMIC RESEARCHERS

This research study only limited to identify the applicability of RCM approach for maintenance optimisation of thermal power plants in Sri Lanka. Therefore the following recommendations are offered to the academic researches to carry out further research.

- Conduct in depth study regarding applicability of SRCM approach for other facilities such as healthcare facilities, data centers, manufacturing facilities for maintenance decision making
- Study the relationship between per unit cost of electricity generation and current maintenance practice
- Conduct in depth study regarding the scientific techniques of optimum maintenance interval determination for maintenance decision making
- Explore the available software application developed for RCM base maintenance planning and implementation together with applicability of such software packages for Sri Lankan facilities

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APPLICATION OF GREEN BUILDING CONCEPT TO ENHANCE INDOOR ENVIRONMENTAL QUALITY IN HOSPITAL BUILDINGS IN SRI LANKA

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ABSTRACT

Through the number of factors, which can attract the occupants to the building, "quality" gets a predominant situate. Among the other buildings, hospitals are most important place which has to maintain quality in high standard. Hence, most of the countries are initiating various strategies to improve quality of hospitals because, it directly affects to the occupant satisfaction of the hospital. Further, hospital is mostly a public place which is extremely noisy, crowded and less indoor environment quality. It causes serious impacts on patient and staff outcomes ranging from sleep loss and elevates blood pressure among patients to emotional exhaustion and burnout among staff. Henceforth, poorly designed hospital environments pose a serious threat on building occupants. Literature findings further said that in current scenario, the majority of occupants are not satisfied with their indoor environment quality in a hospital.

Nowadays, most of hospitals are following various strategies to improve quality of indoor environment. Among those strategies, green building concept becomes most prominent which is easy to adapt to improve the indoor environment quality. Moreover, green hospital design has been linked to better patient outcomes and staff retention. Even though, in past few years many newly constructed and renovated buildings moved towards green, buildings in hospital sector in Sri Lanka has not much familiar with the green building concept. Therefore, this study is mainly focused on presenting the importance of applying green building concept in hospital buildings to improve indoor environmental quality. Two case studies consisting private and public hospitals were conducted to collect the data. Six semi-structured interviews were conducted who have caught up in operational and maintenance management process of selected hospitals. As revealed by research findings, there was no special attention to enhance indoor environment quality in Sri Lankan hospitals especially in public sector. Therefore, several issues were identified comply with the indoor air quality, thermal comfort, acoustic comfort, visual comfort and spatial comfort. Indoor Air quality is one of the major challenges faced by many hospital buildings as it creates several issues within hospital environment. Accordingly, probable green strategies were proposed to overcome identified indoor environment quality issues in hospital buildings to facilitate high quality indoor environment for building occupants in hospital buildings in Sri Lanka.

Keywords: *Green Building Concept; Hospital Buildings; Indoor Environmental Quality; Occupants' Satisfaction.*

1. INTRODUCTION

Employee comfort, flexibility, accessibility and privacy, all depends on the physical work environment. An unsatisfactory physical environment can lead to occupant dissatisfaction. Concern about hospital sector, a study by Whitehead *et al.* (2007) stated that "hospital environment may be a determining factor in the choice of hospital" (p.4). When considering the importance of occupant's satisfaction relating to hospital sector, it is important to satisfy staff and patients about the indoor environment quality of a hospital. Pantouvakis and Mpogiatzidis (2013) found that job satisfaction of doctors is directly related to the quality of services provided. Further explained job satisfaction in healthcare employees affects job quality, effectiveness and efficiency and at the same time the cost of services provided. Furthermore, Patient perception on health care has become an important aspect in determining the quality of health care. It has been also highlighted that patient satisfaction is essential to ensure continuity of care and better patient compliance with treatment, and thereby a favourable clinical outcome (Senarath *et al.*, 2013). Hence, the

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staff consisted of hospital whose job role exposed them regularly to a wide range of hospital environment. Consequently, creating satisfactory level of hospital environment is more essential for both staff and patients.

Green Rating System for Built Environment (GBCSL, 2010) found that many countries have developed sustainability guidelines and official recognition systems based on issues that those countries are facing in the present context. At the present time green building concept is widely becoming more implementing. Green building brings together a huge collection of practices and techniques to reduce and ultimately environment eliminate the impacts of building on the environment and human health while Green buildings typically contribute to improve employee health, comfort and productivity. Paul and Taylor (2007) found that green buildings have a better indoor environmental quality than conventional buildings and that this translates into a more satisfying workplace for the building's occupants and more productive workforce. Raghupathy (2010) stated that the differences between conventional buildings and green buildings are green buildings conserves natural resources, concern for human comfort, indoor environment and productivity. For this reason green hospital design has been linked to aspiring better patient outcomes and staff retention. Raghupathy further mentioned that green hospital's patient recovery much faster with connectivity to outside environment and healing benefits for patients. In addition better indoor air quality with no sick building syndrome, regular CO_2 monitoring, increased fresh air ventilation are other rewards. Hence, in the past few years, a number of newly constructed and renovated hospital buildings have strived for and received LEED certification. However, Withanachchi *et al.* (2004) reported hospitals of developing countries have significant limitation of resources. Shortage of funds, lack of precedence setting on quality of service, inadequacy of training on hospital management and low public awareness on quality of hospital service are the obstacles to performance improvement of the public health sector. Similarly in Sri Lanka, the concern on moving hospital buildings towards green building concept is considerably less and most of healthcare providers neglect the psychosocial aspect of health care.

Therefore, this study is expected to identify IEQ issues in hospital buildings in Sri Lanka in order to suggest probable green strategies to overcome such identified issues. The secondary data relating to the IEQ and green buildings are discussed in next section.

2. LITERATURE REVIEW

2.1. INDOOR ENVIRONMENTAL QUALITY

Indoor environment, which is restricted space consist with complex and dynamic combination of physical, biological, and chemical factors that can affect the occupants health and physical reactions anytime whether realise it or not (Kamaruzzaman and Sabrani, 2011). The physical parameters describing a thermal indoor environment a large number of further parameters have an impact on the occupant satisfaction and the workspace acceptance. Moreover, these are not only physical parameters related to air quality, visual or aural comfort but also social and architectural aspects related to a specific workspace (Kim and Dear, 2006).

Studies by various researchers (Hui *et al.*, 2009; Kim and Dear, 2006) found that the occupant acceptance regarding the perceived IEQ was correlated with four major environmental factors:

- Thermal Comfort
- Indoor Air Quality (IAQ)
- Acoustic Comfort
- Visual Comfort

Furthermore, (Frontczak *et al.*, 2012) found that other than above factors, there are number of parameters represent by the IEQ.

- Spatial Comfort
- Building Maintenance and Cleanliness

According to Clements-Croom (2000) indoor environmental quality should take into consideration more than above factors. It also should include;

- Colour schemes
- Building materials
- Radiation and electromagnetic fields

Henceforth, many factors can be identified under IEQ which should consider in improving indoor environment of hospital buildings for high customer satisfaction. However, Indoor Air Quality, thermal comfort, visual comfort, acoustic and special comfort factors have been considered in this research as the IEQ factors influencing occupants' satisfaction.

2.2. INDOOR ENVIRONMENTAL QUALITY IN HOSPITAL BUILDINGS

When considering the importance of occupant's satisfaction relating to hospital sector, it is important to satisfy staff and patients about the indoor environment quality of a hospital. Pantouvakis and Mpogiatzidis (2013) found that job satisfaction of doctors is directly related to the quality of services provided. Further explained job satisfaction in healthcare employees affects job quality, effectiveness and efficiency and at the same time the cost of services provided. Furthermore, Patient perception on health care has become an important aspect in determining the quality of health care. It has been also highlighted that patient satisfaction is essential to ensure continuity of care and better patient compliance with treatment, and thereby a favourable clinical outcome (Senarath *et al.,* 2013).

However, Withanachchi *et al.* (2004) reported that the hospitals of developing countries have significant limitation of resources. Shortage of funds, lack of precedence setting on quality of service, inadequacy of training on hospital management and low public awareness on quality of hospital service are the obstacles to performance improvement of the public health sector. Similarly in Sri Lankan context (Senarath *et al.,* 2013), it is reported that healthcare providers mostly neglect the psychosocial aspect of health care however its importance has been emphasised in many studies. Therefore, adapting green concept for hospitals in Sri Lankan context also may be more effective.

2.3. GREEN BUILDING CONCEPT

Batuwangala (2000) explained that green building concept, in broader terms, involves a building, which is designed, built, operated, maintained or reused with objectives to protect occupant health, improve employee productivity, use wisely natural resources and reduce the environmental impact. Rashid *et al.,* (2012) explained that any building with a Leadership in Energy and Environmental Design (LEED) certification from the US Green Building Council (USGBC) is considered a "green building". The United States Green Building Council (USGBC) defined green buildings as ones that have significantly reduced or eliminated negative impacts on the environment and the occupants. In 2000, USGBC launched the first formal framework for rating green buildings in the US; Leadership in Energy and Environmental Design (LEED). The rating system's structure consists of five categories: sustainable sites, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality (Abbaszadeh *et al.,* 2006). Batuwangala (2000) found that it should also be emphasised that green buildings do not only contribute towards a sustainable construction and environment but it also brings lots of benefits and advantages to the building owners and the users. It contributes towards lower development costs, lower operating costs, increased comforts, healthier indoor environment quality, and enhanced durability and less maintenance costs (Batuwangala, 2000).

2.4. INDOOR ENVIRONMENTAL QUALITY IN GREEN BUILDINGS

According to GBCSL (2011), there are number of researches and publications on assessment of sustainability considering various domains with different sustainability approaches. Although there are various rating systems are used globally, the below Table 1 states green strategies in few rating systems relating to the indoor environment quality.

Table 1: Green Building Strategies Relating to IEQ

Rating Scheme	Factors	Description	Strategies
LEED (USA)	Indoor Air Quality	Minimum IAQ performance	Meet the minimum requirements of ASHRAE 62-1999.
		Environmental Tobacco Smoke (ETS) Control	Prohibiting smoking inside the building or installing smoking rooms.
		CO_2 Monitoring	Install a permanent CO_2 monitoring system.
	Thermal Comfort	Thermal Comfort	Compliance with ASHRAE 55-2012.
		Thermal Comfort, permanent monitoring system	Install a permanent temperature and humidity monitoring system.
	Visual Comfort	Daylight and views	Daylight 75% of space and views 90% of spaces.
Green Globes (Canada)	Indoor Air Quality	Ventilation System	Provide ventilation in accordance with ASHRAE 62.1-2004.
		Control of indoor pollutants	Implement design measures to prevent growth of bacteria on building surfaces and in concealed spaces.
	Lighting	Lighting	Provide ambient daylight to 80%of the primary spaces
			Provide views to the building exterior, from all primary interior spaces.
	Thermal Comfort	Thermal Comfort	Achieve compliance with ASHRAE 55-2004 for the thermal comfort.
	Acoustic Comfort	Acoustic Comfort	Specify acoustic controls to meet the acoustic privacy requirements.
BREEAM (UK)	Acoustic comfort	Minimising sources of air pollution	Removal of contaminant sources.
	Indoor Air Quality	Potential for natural ventilation	Occupied spaces of the building are designed to be capable of providing fresh air entirely via a natural ventilation strategy.
	Spatial Comfort	Space allocation for healthcare buildings	Some openings in public and patient areas need to be provided with restricted opening areas of not more than 100mm.
HK BEAM (Hong Kong)	Indoor air quality	Natural ventilation	Compliance with ASHRAE 62.1-2010 for minimum ventilation rate and outdoor air quality
		Outdoor source and indoor source air pollution	Ensure minimisation of odor from waste collection system and comply with the building regulations

Source: Boonstra and Pettersen (2003); Wallhagen (2010); GBCSL (2011)

Similarly in GREENSL local rating system, there are many green strategies of IEQ can be identified as mentioned in below Table 2.

Table 2: IEQ Strategies in GREENSL

Factors	Description	Strategies
Indoor air quality	Minimum IAQ Performance	Meet or exceed the minimum outdoor air ventilation rates as described in the ASHRAE 62.1-2004 standard. Balance the impacts of ventilation rates on energy use and indoor air quality to optimise for energy efficiency and occupant health.
	Smoke (ETS) Control	Attain zero exposure of non-smokers to environmental tobacco smoke.
	Increased Ventilation	For Mechanically ventilated Spaces: Use heat recovery, where appropriate, to minimise the additional energy consumption associated with higher ventilation rates.
	Indoor Chemical and Pollutant Source Control	Design facility cleaning and maintenance areas with isolated exhaust systems for contaminants. Maintain physical isolation from the rest of the regularly occupied areas of the building.
Thermal comfort	Thermal Comfort, Design	Establish comfort criteria per ASHRAE Standard 55-2004 that support the desired quality and occupant satisfaction with building performance. Design building envelope and systems with the capability to deliver performance to the comfort criteria under expected environmental and use conditions.
		ASHRAE Standard 55-2004 provides guidance for establishing thermal comfort criteria and the documentation and validation of building performance to the criteria.
Visual comfort	Daylight and Views	Design the building to maximise day-lighting and view opportunities. Strategies to consider include building orientation, shallow floor plates, increased building perimeter, exterior and interior shading devices, high performance glazing, and photo-integrated light sensors. Achieve a minimum Daylight Factor of 2% (excluding all direct sunlight penetration) in 75% of all space occupied for critical visual tasks.

Source: GBCSL (2011)

There are many green strategies can be identified in many green rating systems that can be applied to overcome the IEQ issues in hospital buildings towards improving staff and customer/patients satisfaction. The basic concepts and green strategies were identified in literature review while next step was to identify IEQ issues and suggestions on possible improvements. To achieve such objectives of this research, the methodology applied in this research is described in next section.

3. METHODOLOGY

For a systematic research it is necessary to follow a research process containing a series of steps. Therefore, it is necessary to design the research systematically for its success in reaching the expected achievement and objectives.

Hence, a comprehensive literature survey was conducted to identify the relationship between occupant's satisfaction and IEQ and to explore available green building strategies in locally and globally and to get a basic idea about green building concept and importance of adaptation to improve indoor environment quality in hospital buildings. The data were collected through case study approach under qualitative phenomena. Two cases were selected as private and public hospital buildings under multiple case study design.

Table 3: Case Description

Case 01	Private hospital buildings	Interview A
		Interview B
		Interview C
Case 02	Public hospital buildings	Interview A
		Interview B
		Interview C

The cross-case analysis technique was used within this research as a suitable data analysis technique because; the research contained two case studies. In analysing collected data of individual cases, code-based content analysis technique was used. Further, this research strengthen the cognitive mapping process by using Decision Explorer software package (Version 3.1.2 – academic, produced by Banxia Software Ltd), which was originally developed to support particular form of cognitive mapping.

4. RESEARCH FINDINGS AND DISCUSSION

The empirical findings reveal that there was lot of issues relating to the indoor environment in hospitals. Summarised issues can identify by referring the Figure 1. As stated by many of the professionals in case studies evaluated, many issues were identified relating to the indoor air quality, thermal comfort, acoustic quality and special comfort etc.

As mentioned by the professionals interviewed in two case studies, improper exhaust fan system, less CO_2 monitoring system, insufficient ventilation are the major issues relating to IAQ. Further, IAQ is one of the major environmental quality issues which directly affect patient and staff health and wellbeing. Thus, their satisfaction on hospital environment can be reduced by poor IAQ. Thermal comfort and acoustic comfort related issues in hospital buildings are another major aspects highlighted by the case study findings. In addition, visual comfort related issues were examined due to less control on lighting levels, inefficient lighting, whilst issues relating to spatial comfort and building maintenance which should also be considered.

One of the difficulties in studies such as this is finding suitable strategy to enhance indoor environment quality in Sri Lankan hospital building. By referring literature it is no doubt that the green strategies helps to enhance the quality of indoor environment. Especially for the hospital buildings adapting green guidelines directly affects to the improve occupants satisfaction relating to their indoor environment. Although Sri Lanka is not familiar with the green building concept it provides necessity of applying green strategies for Sri Lankan hospital sector to improve IEQ. Furthermore it reveals role of GBCSL and how far it can apply for the hospital sector in Sri Lanka. The probable green strategies to overcome identified IEQ issues in hospital buildings are suggested in this research as follows.

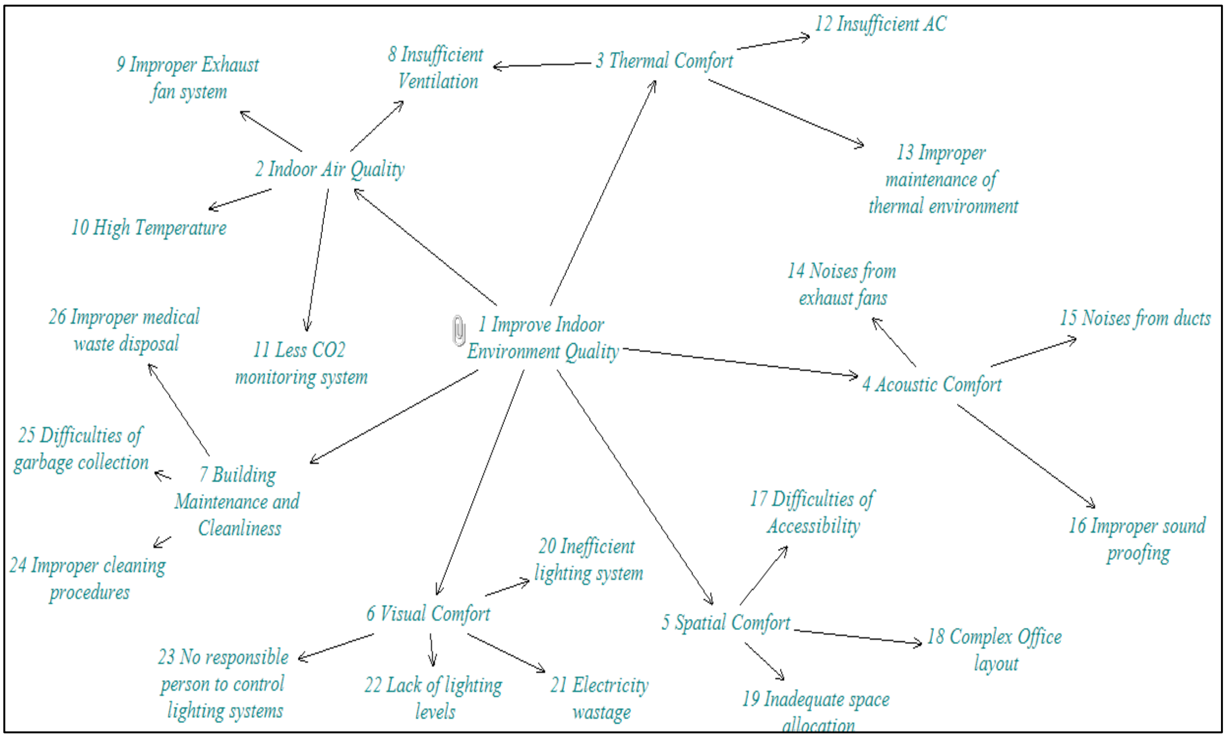

Figure 1: Cognitive Map of IEQ Issues in Hospital Buildings

4.1. *PROPOSED GREEN STRATEGIES*

Indoor Air Quality

For the identified issues through semi-structured interviews and direct observations which are summarised as inadequacy ventilation, improper exhaust fan system, unbalanced temperature, less CO_2 monitoring system. According to the green building concept, there are various strategies introduced by various rating schemes such as LEED, Green Globes, BREEAM, and HK BEAM. Consider on strategies of green building council of Sri Lanka it defines some strategies which can apply to overcome identified issues.

According to green rating systems available, it is needed to design mechanical ventilation systems using the ventilation rate. Also that system must meet or exceed the minimum outdoor air ventilation rates as described in the ASHRAE 62.1-2004 standard. Then after through the proper ventilation system IAQ can be enhanced. Other important strategy is minimise exposure of building occupants, indoor surfaces and ventilation air distribution systems to Environmental Tobacco Smoke (ETS). It is required to improve indoor air quality by prohibiting smoking inside the building. If it is located it must be designated at least 25 feet away from entries. Permanent CO_2 monitoring systems are essential to provide indoor air quality. Also monitor CO_2 concentrations within all densely occupied spaces and install CO_2 and airflow measurement equipment also creates proper CO_2 monitoring system. Further as a hospital it is needed to increase breathing zone outdoor air ventilation rates, minimise exposure of building occupants to potentially hazardous particulates and chemical pollutants and design facility cleaning and maintenance areas with isolated exhaust systems for contaminants are also essential to improve occupants' satisfaction.

Visual Comfort

Provide a high level of lighting system control by individual occupants or by specific groups in multi-occupant spaces and provide individual lighting controls for 90% (minimum) of the building occupants are some of strategies introduced by green building council in Sri Lanka to increase visual comfort. Other than those strategies connecting indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building also solve problems regarding visual comfort. According to their standards, it is must to achieve a minimum daylight factor of 2% in 75% of all space occupied for critical visual tasks and design the building to maximise day-lighting and view opportunities also important.

Therefore, insufficient lighting system, electricity wastage related issues can mitigate by adapting above mentioned strategies.

Thermal Comfort

According to the empirical findings, insufficient air conditioning, improper humidity level and some issues identified due to improper maintenance of thermal environment. Considering the strategies of green building council relating to thermal comfort, it is must to provide comfortable thermal environment to improve occupants' satisfaction especially better patient outcome. Hence it is needed to design HVAC systems and the building envelope to meet the requirements of ASHRAE Standard 55-2004 and establish comfort criteria per ASHRAE Standard 55-2004.

Spatial Comfort

According to the green strategies, it is important to provide public recreational areas such as parks, lakes and development should address all levels of accessibility requirements. Further to gain comfortable spatial comfort, it is must designing the building, layout and planning, addressing the issues of privacy and safety of all types of users. Applying above mentioned techniques it automatically solves problems regarding accessibility, inadequate office layout and other issues on insufficient space allocation.

5. SUMMARY AND CONCLUSIONS

Research in most healthcare facilities has shown that good indoor environment quality factors are positively perceived and valued by the occupants and users of those building spaces. Indoor environments also impact objective results in healthcare such as clinical outcomes. Therefore, suitable and specific green design strategies can be benchmarked and evaluated on their performance thoroughly. However, the consideration on the indoor environmental quality is less in most of hospital buildings in Sri Lanka. Hence, it feels necessity of adapting any guideline or strategy for maintain their indoor environment. As previous researches proved that the occupants in green buildings were more satisfied with indoor environment quality in their workspace. Similarly in hospital buildings, which has obtained green certification shows high quality indoor environment rather than non-green hospital environment. Hence, several IEQ issues were identified relating to non-green hospital buildings through this study. Among those factors, poor IAQ is one of the major factor affecting patient and staff outcome and satisfaction. In addition, several issues relating to IEQ aspects were identified by case studies findings such as, uncomfortable thermal environments, spatial issues, acoustical comfort related issues etc. Finally, suitable green strategies were suggested based on existing local and international green rating systems and relevant standards. Accordingly, practicable attributes from green building concept were suggested that can be used to enhance occupants' satisfaction in hospital buildings in Sri Lanka.

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BETTER VALUES AND CHARACTERISTICS IN RELATIONALLY INTEGRATED VALUE NETWORKS TO ENHANCE TOTAL ASSET MANAGEMENT

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ABSTRACT

Construction contract types span a wide spectrum ranging from traditional contracting to relational contracting modes. Although weak collaborative supply chain networks exist even in widely practiced traditional contract modes, the potentially beneficial strong relational forces remain untapped and/or fragmented, lacking well-defined common goals among stakeholders. Apart from addressing this shortfall in the built asset planning, design and construction (project management) phase, relational contracts (RC) can also be extended to total asset management (TAM) by aiming at the relational integration of all stakeholders throughout the built asset lifecycle, by engaging them in cross linked value networks'. Such integrated networks were called 'relationally integrated value networks' (RIVANS) when initially proposed for the project management phase. 'RIVANS for TAM' were next proposed to provide a holistic approach to bridge the project management phase and the asset management phase in the lifecycle of assets. The study reported in this paper, contributes to knowledge by identifying better values through adapting RIVANS as a holistic beneficial approach to the whole built environment.

A questionnaire survey was conducted to identify common better values in RIVANS. These identified better values were then clustered to form similar groups using factor analysis to establish synergetic characteristics of RIVANS. Four characteristics were extracted to identify and target embedded synergies in RIVANS, for enhanced total asset management.

Keywords: *Better Values; Characteristics; Relational Contracts; Relationally Integrated Value Networks; Total Asset Management.*

1. INTRODUCTION

Successful implementation of relational contracts requires strong commitment and continuous understanding at all levels. The trend towards consideration of relational contracts, alliance-type contracts has encouraged increased focus on the collaborative elements of design and construction (DC) of infrastructure project management (IPM) phase and operation and maintenance (OM) of infrastructure asset management (IAM) phase. Kumaraswamy *et al*. (2004) further highlighted, that interaction and communication between these two phases are usually limited in the traditional procurement approaches where transactional force are very limited, resulting in weak collaborative supply chain networks. Therefore, problems such as unrealistic expectations, incomplete requirements, insufficient resources/ schedule, lack of management support, poor planning, changing requirements, and lack of users' involvement are common in the traditional procurement approaches (Yu and Shen, 2013). However, with increased attention on customer satisfaction, sustainable buildings, life cycle cost, flexible designs, designing and constructing for maintainability, interaction and working relationship between IPM and IAM has also become increasingly important. Thus, value networks with common goals shared among project

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teams focus on optimising relational integration of these teams through integrated processes that generate synergies, were identified as a better approach (Kumaraswamy *et al*., 2010; Famakin *et al*., 2012; Ling *et al*., 2014). These strengthen relational forces within client - led supply chain networks in IPM and IAM to achieve higher performance (Segerstedt and Olofsson, 2010).

Relationally Integrated Value Networks (RIVANS) have been proposed as a holistic conceptual framework for relational integration, where project participants are engaged in cross-linked value networks (Kumaraswamy *et al*., 2011). Further, RIVANS framework extends beyond the typical structural integration approaches such as in procurement modes like Design - Build (DB) or Design Build-Operate (DBO) (Kumaraswamy *et al*., 2010). RIVANS is based on identifying common better values of the entire relational network (including the client, consultants, contractors and suppliers in the supply chain), building better relationships - mostly by jointly focusing on, and working towards such common shared values. Thus, RIVANS envisions an ensuing spiral of improving value and strengthening relationships that continue to mutually reinforce and "feed" one another. Thus, the objective of the paper is to discuss applying RIVANS to target potential better values and improved practices that bridge the current divides between IPM and IAM. The following section discusses common values of relationally integrated value networks highlighted in the literature.

2. POTENTIAL BETTER VALUE BY LINKING USUAL SUPPLY CHAINS IN IPM WITH IAM

Functional integration implied consensus across functions and merged in to a single entity (Karlsson *et al.*, 2010). Literature highlighted that (Weerapperuma *et al*., 2013; Ling *et al*., 2014), exploitable synergies between DandC and OandM such as sharing relevant information, joint use of ICT tools, integrated team building, arranging common linked resource pool and requirement and integrated business continuity management can potentially best achieve 'better value' through functional integration than other integration types.

2.1. SHARING RELEVANT INFORMATION

Sharing relevant information is very critical for project management; uncertainty management and risk analysis that have an effect on the project's achievement of quality, budget and schedule requirements (Karlsen, 2010). Further, sharing information can be modelled as mechanism to prevent problems such as asymmetry and mistrust among the project stakeholders. It can also formulate to make node enterprises of supply chains to achieve order form strategy, construction capacity allocation, resource allocation and etc. (Zhang and Ng, 2012). As such, the influence of information flow on supply chains is a long and dynamic process related to functional coordination of project supply chains (Fox, 2009).

2.2. ADDRESSING SUSTAINABILITY ISSUE

As a whole, sustainability covers the entire cycle of a project and hence, sustainable infrastructure project is drive inception through delivery to life cycle use and finally disposal (Ugwu and Haupt, 2005). Therefore, it would enable stakeholders (specifically designers) to take appropriate proactive measures to ensure sustainable and maintainable design and construction as part of innovative infrastructure delivery (Lam *et al.*, 2011). Optimised energy use, operation cots, safety in use, need for maintenance are some benefiting traces in addressing sustainability issues at early stages such as planning and development.

2.3. INTEGRATED BUSINESS CONTINUITY MANAGEMENT

Business Continuity Management (BCM) and Continuity of Operations (COOP) is a multi-dimensional practice requiring a balance of investment against risk to the enterprise. Business continuity planning is however more than just a simple task of setting out certain contingency plans and avoiding risks. It hence, refers to its ability to have a focused response management to deal with the situation once the consequences are known (Iyer *et al.,* 2000). BCM has reduced losses from the interaction of the equity, flexibility and alignment goals of management, workers and society (Low *et al.,* 2010).

2.4. *JOINT USE OF ICT TOOLS*

Infrastructure projects involve collaborative working among multiple enterprises. Project managers are required to facilitate the integration of work of all stakeholders, while project team may be geographically separated beyond national boundaries or, in the different context of countries (Adriaanse *et al.,* 2010). The effective communications between project stakeholders is being important for the project success and it can be achieved through Information Communication Technologies (ICT). However, more advanced applications such as three and four dimensional modelling, Building Information Management (BIM) applications global positioning systems and internet technology are still at their adolescent stages (Ahuja *et al.,* 2010).

2.5. *LIFE CYCLE OPTIMISATION OPTIONS/OPPORTUNITIES*

When designers have more knowledge of operational and maintenance issues and asset managers have better understanding of design intent and material equipment choices, it could create better opportunities to achieve life cycle optimisation options (Yang *et al.,* 2011). Life cycle optimisation is focuses on the total costs that occur during a project life cycle in two dimensions; estimating costs on a whole life basis and monitoring the cost incurred throughout the project life (Korpi and Risku, 2008). Therefore, it is necessary to comprehend the interaction of the cost items that accumulate among the relevant stakeholders during the different stages of project life cycle.

2.6. *INTEGRATED TEAM BUILDING (ITB)*

Clients and other stakeholders working together as a team can enhance whole-life value through reducing total cost and improving performance, to deliver a project effectively than in a traditional fragmented relationship that is often adversarial. Collaborative working is the underline core requirement for integrating teams. Thus, Team-working is characterised by mutual trust and openness, where problems and risks are shared and resolved collectively by the integrated project team. ITB balances three competing quality targets; equity, flexibility and alignment of cooperate objectives (Aghazadeh, 2003). However, the benefits of this would rely on team’s ability of meeting customer’s expectation (Langbert and Friedman, 2002).

2.7. *COMMON LINKED RESOURCE POOL*

This encompasses people skills, technologies, applications, and business processes to make better strategic and tactical decisions in infrastructure projects. Thus, it plays a crucial role in achieving competitive advantages (Kapoor and Sherif, 2012). Further, this ensures the maximum use of resources. Thus, IPM team and IAM team are encouraged to integrate to make use of common resource pools. Ultimately, this grants and ensures smooth functionality between DandC and OandM stages.

2.8. *EXPANDED LONG TERM BUSINESS OPPORTUNITIES*

Fuelled by collaborative technologies that allow new ways of organising and changing from a process-centric view of work to human-centric view of project due to its value creative networks (Alee, 2008). The impact of the long term business opportunities is likely to be significant and to generate shareholders’ capital gains (Hughes, 1995). Therefore, this better value/synergies directs purposeful group of people who come together to take action in project and strengthen powerful new practices and merits for managing collaborative works through human interactions (Jarvealainen, 2012).

3. RESEARCH DESIGN

Research was designed to identify its objectives through an industry-wide questionnaire survey. Since client, consultant, contractor, sub-contractor, supplier, academia and developer are the main parties dominating the project management and asset management industry and its practices; it was decided to elicit their knowledge as experts‟ views to explore the research objectives.

3.1. Sample Selection

The survey sample was selected randomly (using simple sampling methods). The contact list of leading clients, consultant, contractor, sub-contractor, supplier and developer of the infrastructure sector was taken from the Institute for Construction Training and Development (ICTAD) registry, telephone directory, leading organisation, respective professional institutions. However, due to the limited time and other several constrains, number of questionnaires were limited to 35. The vacuum in the knowledge extraction due to number of questionnaires of the survey was minimised by selecting key persons from large projects and asset management organisations.

3.2. Questionnaire Design and Questionnaire Survey

Led by the third author, a multi-country research project was undertaken in Hong Kong, Singapore, Sri Lanka and the UK to investigate ways to integrate PM and AM supply chains to achieve better value. The survey questionnaire developed for above purpose is used to investigate the situation in Sri Lanka.

The questionnaire was developed into three sections. Several important questions were grouped under section one to identify the potential better value/synergies by linking the usual supply chains in IPM and IAM. Ten such factors were given in this section and responses were asked to rank on a five-point Likert scale (1= Strongly Disagree, 2=disagree, 3=Neutral, 4= Agree and 5=Strongly Agree) (refer Table 1). Section two was focused to identify achieving value through integration under three categories "Functional Integration", "Relational Integration", and "Transactional Integration". Further eleven common goals were listed in this section to seek the respondents‟ opinions on the importance, in achieving "better value through above synergies. They were asked to rank the importance of listed common goals using a five point Likert scale where, 1= Not important at all, 2=Not so important, 3=Neutral, 4= Important and 5=Very important. Section three was focused to identify key stakeholders of "D and C" and "O and M" value networks. Therefore, 11 of stakeholders were listed and respondents were asked to rank using the same five point Likert scale. The data for this paper was taken from the first section of the questionnaire (Table 1).

Table 1: Questions Used for Studying Potential Better Value / Synergies by Linking the Usual Supply Chains in IPM with the Usual Supply Chains in IAM

Better Value / Synergies
1. Better Value / Synergies arise from <u>sharing relevant information</u> (e.g. building specs, as-built drawings, construction records, O and M (Operation and Maintenance) performance data, etc.) - *between* 'D and C' (Design and Construction) *and* 'O and M' teams
2. Better Value / Synergies arise from addressing Sustainability issues more effectively through above sharing of relevant information
3. Better Value/Synergies arise from similar procurement protocols between 'DandC' and 'O and M'
4. Better Value / Synergies arise from better (integrated) 'life cycle optimisation' options/ opportunities e.g. when Designers have more knowledge of OandM issues *and* Asset Managers have better understanding of design intent and material/ equipment choices
5. Better Value / Synergies arise from overlapping Supply Chain Networks delivering 'DandC' and 'OandM'
6. Better Value/ Synergies arise from arranging for some common/ linked resource pools and requirements (e.g. in material types, human resources) between 'DandC' and 'OandM'
7. Better Value / Synergies arise from expanded long term business opportunities
8. Better Value / Synergies arise from integrated team building (Human resource capacity improvement)
9. Better Value / Synergies arise from joint use of ICT tools (e.g. in BIM – Building Information Modeling)
10. Better Value / Synergies arise from integrated 'business continuity management' opportunities

The questionnaire survey was started from a pilot survey which was carried out to ensure the reliability of the survey. Three experts were involved in this task and their feedbacks were used to fine-tune the format of the questionnaire. The improved version of the questionnaires was used to collect data, through a web based survey.

4. RESULTS AND DISCUSSIONS

Potential better values by linking usual supply chains in design and construction (DC) and operation and maintenance (OM) was established using t-test and were discussed in a previously published paper from this research (Weerappuruma *et al*., 2013). Further, factor analysis (FA) was carried out to identify leading characteristics of RIVANS, through identifying dominating factors. FA is a statistical tool to identify if there is any further relationship among the measures. FA was conducted using the Statistical Package for Social Science (SPSS). Table 2 shows all possible number of factors extractable and the loadings after rotation. The important factors are those whose eigenvalues are greater than or equal to 1, since an eigenvalue is a measure of how a standard variable contributes to the principal components. A component with an eigenvalue of less than 1 is considered as less important and can therefore be ignored and omitted. The eigenvalues corresponding to the each factor are shown below to the factor number in the table. The table also shows the rotated factor loadings and commonalities (h^2). Simply, a factor loading can be expressed as a correlation coefficient between an original variable and an extracted factor. Commonality is a measure of variance in the variable that has been accounted for its factor extraction. To minimise the number of factors and increase the factor loadings, factor rotation is carried out with "varimax" rotation.

Table 2: Rotated Factor Matrix

Better Values	**Factor 1 (2.9)**	**Factor 2 (2.0)**	**Factor 3 (1.4)**	**Factor 4 (1.2)**	h^2
Integrated team building	0.929				0.866
Joint use of ICT tools	0.927				0.583
Expanded long term business opportunities	0.525				0.731
Overlapping supply chain networks delivering DC *and* OM teams		0.842			0.693
Arranging for some common/ linked resource pools and requirements between DC *and* OM		0.836			0.839
(integrated) 'life cycle optimisation' options/ opportunities		0.700			0.772
Integrated 'business continuity management' opportunities			0.819		0.407
Addressing sustainability and maintainability issues more effectively through sharing of relevant information			0.754		0.928
Sharing information between DC *and* OM teams				0.908	0.873
Similar procurement protocols between DC and OM teams				0.619	0.803

Next section of this paper discusses characteristics of RIVANS extracted through factors analysis. These factors are labelled as:

Factor 1: Building long term integrated networks
Factor 2: Setting a common pool linking DC and OM
Factor 3: Enhancing sustainability of TAM
Factor 4: Developing a similar protocol between DC and OM

4.1. BUILDING LONG TERM INTEGRATED NETWORKS

The most important characteristic (i.e. first factor) in RIVANS, with an eigenvalue of 2.9 is labelled as "building long term integrated networks". This factor consists of three better values (refer Table 2). Integrated team building (ITB) is a potential better values/synergies that could build a long term integrated network among teams in DC and OM. Integrated team building aligns goals of management; employees and society and thus meets the customers' satisfaction (Langbert and Friedman, 2002; Aghazadeh, 2003). Therefore, it is important that the teams to work together to strengthen powerful new practices and merits for managing collaborative works through human interactions (Jarvealainen, 2012).

In building integrated networks, it involves collaborative working among multiple enterprises (Adriaanse *et al*., 2010). For instance at the PM phase, project managers are required to facilitate the integration of work of all the stakeholders. Thus, effective communications between these teams is important for the success and joint use of Information Communication Technology (ICT) tools are highlighted as effective (Ling *et al*., 2014). However, ICT is commonly used for many standalone applications for book keeping and two-dimensional drawings during both IPM and IAM phases in the local practices. Further, practising of more advanced applications such as three and four dimensional modelling, Building Information Management (BIM) applications, global positioning systems and internet technology are still at a primitive level.

Further, creating long term business opportunities is a significant benefit in these integrated networks (Hughes *et al*., 1995; Alee, 2008). Moreover, successful outcome is achievable in terms of time, cost and quality and also it leads to establish stronger commitments and closer bonds (Palaneeswaran *et al*., 2003). However, local expert mentioned that creating a "monopoly" along with these long-term business relationships could be a latent risk in these expanded long terms business opportunities.

4.2. SETTING A COMMON POOL LINKING DC AND OM

The second characteristic identified by the factor analysis is setting a common pool linking DC and OM. The eigenvalue obtained for this factor is 2.0. This factor has three better values that are positively correlated (refer Table 2). Overlapping supply chain networks in DC and OM may eventually form a common pool where material, information and services can be pooled. In general, relational contracts allow teams to pool their resources including financial resources, knowledge, expertise, technology and skills for joint management (Carrillo, 1996; Walker and Johannes, 2003). For instance in the local practice, joint ventures which is the most common relational contracting approach in Sri Lanka, are formed in situations where the resources of one contracting company are not enough to carry out a certain project and further companies seek new business opportunities through the strengths of the other partners such as reputation, stable position, business relationships etc. Thus, there is an avenue created for setting a common pool under current practices. However, it is at its adolescent stage in the local industry.

Further, life cycle optimisation is a value addition of forming a common pool for proper assembling of information and material in an integrated way. This could provide an immense opportunity for effective decision making, when designers have more knowledge of operation and maintenance issues and facilities managers have better understanding of design intent and material/ equipment choices through sharing of relevant information through interaction and working relationship between DC and OM phases. For instance, the life cycle relationship between these phases of infrastructure projects gives better valuing decisions, focusing on the costs incurred after construction or development (Pelzeter, 2007; Korpi and Risku, 2008).

4.3. ENHANCING SUSTAINABILITY OF TAM

Enhancing sustainability of TAM is the third characteristic comprising a 1.4 eigenvalue. Continuity management of business opportunities in relational contracts yields long-term sustainability of TAM. Business Continuity Management (BCM) and Continuity of Operations (COOP) is a multi-dimensional practice cooperates with sustainability objectives (Iyer *et al*., 2000). Thus, integrated BCM initiatives typically focus on the continuous assessment of business needs, acceptable levels of risks in infrastructure projects to optimise operational availability in the lifecycle (Low *et al*., 2010). This pave the way to address the important issues immediately and motivate the recovery of lags in sustainability and maintainability of infrastructure projects with no delay before propagating into an unrecoverable failure (Bennett and Jayes, 1995; Thomas and Thomas, 2005).

Further, efficient sharing of relevant information would address sustainability and maintainability issues more effectively at early stages of TAM. Sustainability is further underpinned by sharing development methods, techniques and decision support tools that would facilitate sustainable appraisal and decision-making at various project level interfaces (either from conceptualisation to design, construction, operation and decommissioning (Ugwu and Haupt, 2005). Therefore, it would enable stakeholders (specifically designers) to take appropriate proactive measures to ensure sustainable design and construction as part of innovative infrastructure delivery (Lam *et al*., 2011).

4.4. DEVELOPING A SIMILAR PROTOCOL BETWEEN DC AND OM

Fourth important characteristic (i.e. fourth factor) in RIVANS, with an eigenvalue of 1.2 is labelled as "developing a similar protocol between DC and OM. This factor consists of two better values (refer Table 2). Sharing information between DC and OM enables to provide the foundation for development of a similar protocol between DC and OM phases of infrastructure assets. Sharing relevant information is very critical for the project management; uncertainty management and risk analysis (Karlsen, 2010). Information in supply chains can be properly integrated to prevent problems such as asymmetry and mistrust among the stakeholders. Thus, strong cross-links through effective information sharing is critical in RIVANS where more than one party work for the same goal, to prevent conflicts and confusions (Chan *et al*., 2006; Cheng *et al*., 2001; Chan and Kumaraswamy, 1997). For instance, when work done in one phase or one party provides inputs to the other phase or party hence if not communicated properly conflicts and confusions occur impeding the total asset management.

Further, the cross links formed between DC and OM through efficient information sharing can be standardised by adopting similar procurement protocols between these two phases. However, considering for such an attempt is almost neglected in current practices. Further industry experts have lesser faith in developing a similar protocol under local context.

5. CONCLUSIONS

The purpose of this research was to investigate better values in mobilising synergies between DC and OM supply chains and important characteristics in RIVANS. Four (04) characteristics from ten (10) better values (refer Table 2) were identified. They are building long term integrated networks, setting a common pool linking DC and OM, enhancing sustainability of TAM and developing a similar protocol between DC and OM. These factors were analysed in terms of the better values and there inter-relationship with the characteristics.

The most important characteristic in RIVANS, is labelled as "building long term integrated networks". Therefore, it is important to work together to strengthen powerful new practices and merits for managing collaborative works through human interactions. However, local expert mentioned that creating a "monopoly" along with these long-term business relationships could be a latent risk in these expanded long terms business opportunities.

Overlapping supply chain networks in DC and OM may eventually form a common pool where material, information and services can be pooled. Further, life cycle optimisation is a value addition of forming a common pool for proper assembling of information in an integrated way which provide an immense opportunity for effective decision making, when designers have more knowledge of operation and maintenance issues and facilities managers have better understanding of design intent and material/ equipment choices through sharing of relevant information through interaction and working relationship between DC and OM phases.

Continuity management of business opportunities in relational contracts yields long-term sustainability of TAM. Further, efficient sharing of relevant information would address sustainability and maintainability issues more effectively at early stages of TAM. Sustainability is further underpinned by sharing development methods, techniques and decision support tools that would facilitate sustainable appraisal and decision-making at the various project level interfaces. Sharing information between DC and OM enables to provide the foundation for development of a similar protocol between DC and OM phases of infrastructure assets.

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BIM SOFTWARE ENVIRONMENT FOR PROJECTS IN SRI LANKA

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ABSTRACT

The term Building Information Modelling, or BIM, is not alien to Sri Lanka anymore; yet BIM has not become a reality in its construction industry. Being a BIM infant industry, Sri Lanka may wait a long time to adopt BIM by its own initiative. But the scenario will be different if a client demands for BIM. This creates the need that industry is aware of the best strategies suite them to effectively implement a project based on BIM. One of the key questions being asked is; what software should we use? In absence of empirical local knowledge, the only option is to device a solution from published knowledge. In order to achieve this, this paper presents a literature synthesis aimed to identify a suitable BIM software environment for Sri Lanka. By reviewing various aspects such as capabilities of applications, accuracy and sharing of data, information documenting, popularity of software and affordability against the technological aspects, a Plural Software Environment based on IFC data exchange was found to be the preferred solution for Sri Lankan context.

Keywords: *Building Information Modelling; Software Environment; Sri Lanka.*

1. INTRODUCTION

Building Information Modelling, or BIM as it is widely known, is still not a reality in Sri Lanka. Being a BIM Infant Industry (Jayasena and Weddikkara, 2013) and a developing Asian economy (IMF, 2012), Sri Lanka would require unique adoption strategies to make the use of BIM worthwhile. The strategies adopted by the industries in BIM matured or maturing countries in different economic backgrounds are unlikely to be readily suitable for Sri Lankan industry. On the other hand, lack of maturity provides the flexibility to adopt from wider options since the choice is less constrained by losses from current technological investments.

Integrated information and automated systems are key components of BIM workflow. While these may not have been fully achieved even in BIM matured industry due to practical limitations and pending developments (Owen *et al*., 2010), significant achievements are likely to be possible even for a BIM infant industry if technologies are wisely selected. A wide variety of software has been developed for BIM since its early concepts were adopted in building industry more than two decades ago. Arbitrary selection of software can give rise to issues in terms of integration, consistency, accuracy and affordability. To minimise potential issues, an assessment of varying software environments for their suitability for Sri Lankan context is necessary. This paper presents a literature synthesis aimed to identify a suitable BIM software environment for Sri Lanka.

2. ABOUT BIM

BIM is in fact is an acronym representing two separate but consecutive functions and a product; Building Information Management, Building Information Modelling, and Building Information Model (Wong and Fan, 2013). The US National BIM Standards defines "Building Information Modelling (BIM) is digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition" (buildingSMART alliance, n.d.). This is the widely sighted definition for BIM though it is not much helpful for a reader who knows nothing about BIM.

Though BIM became buzzword in recent times, it is not very new. The concept of BIM has been talked about even in early 70's (refer Eastman *et al*., 1974). However, the earliest experience in BIM was presented

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to the building industry only in late 80's with the introduction of Graphisoft's ArchiCAD (Laiserin, 2003). However, it was not yet known as BIM. Graphisoft called it Virtual Building. The earlier concepts were presented with variable terms such as Building Description Systems (Eastman *et al*., 1974) and Building Product Models (Eastman *et al*., 2011). Nevertheless, they all were rooted in the concept presently known as BIM.

BIM as a three letter acronym representing Building, Information, Modelling was coined by architect and Autodesk building industry strategist Phil Bernstein in 2002 who used the actual terms for BIM (Beck, 2008). Autodesk (2003) envisaged at this early stage that, BIM would support the continuous and immediate availability of project design scope, schedule, and cost information that is of high quality, reliable, integrated, and fully coordinated. It may be interesting to critically review how much Construction Software Industry has really achieved in two decades.

The beauty of BIM is that most BIM users need not understand technology behind it. All that is needed for a practitioner to be BIM ready is the capability of effectively using BIM software application(s) relevant to his/her practice. A good example is that many used ArchiCAD for years without knowing that it was a BIM tool. The associated technology opened numerous opportunities by enabling full construction of a building virtually in a computer. In addition to possibility for various simulations for quality and functional performance, BIM enabled automation of number of manual processes in conventional practices.

Most building professionals think that BIM is synonymous to 3D (3 Dimensional) modelling. This is an unfavourable perception that would hinder the proper understanding of BIM. BIM, being an information model is in fact nD. Conceptually, BIM is designed in a manner that it can hold information of any "n" number of information dimensions. For broader comprehension, probing into "open BIM" standards of buildingSMART (2013) is worthwhile.

The international standard for BIM data is Industry Foundation Classes (IFC). It is open source that anybody can freely adopt it (ISO, 2005). Figure 1 is a small portion of IFC BIM model viewed in a Word Processing application. Information is readable by human. For example, #9806 describes a wall element, giving some unique information about it and refers to some other locations in the model file viz. #13, #9803 and #9876, where each refers to model ownership, placement of the building, and geometrical placement of the wall. A particular data is recorded only once in the model and all other instances are reference to this information using hashtags (#"number") (Jayasena and De Silva, 2013). This enables a change in one design parameter of a building element (e.g. storey height) to be automatically reflected in all other related elements (e.g. vertical pipes).

```
…
#13= IFCOWNERHISTORY(#12,#5,$,.ADDED.,$,$,$,1286451639);
...
#36= IFCDIRECTION((0.,0.,1.));
..
#9792= IFCDIRECTION((-1.,0.,0.));
#9796= IFCCARTESIANPOINT((12.,0.,0.));
#9800= IFCAXIS2PLACEMENT3D(#9796,#36,#9792);
#9803= IFCLOCALPLACEMENT(#593,#9800);
#9806= IFCWALLSTANDARDCASE('16DNNqzfP2thtfaOflvsKA',#13, 'Wand-Ext-ERDG-
        4',$,$,#9803,#9876,'A6C3DE63-3731-4F6A-94-7E-DE8A8295779F');
#9825= IFCCARTESIANPOINT((0.,0.));
```

Figure 1: IFC Building Information Model
Source: Jayasena and De Silva (2013)

A BIM model "written" in this manner can be read and interpreted by computers to construct it virtually in their memory to the fullest detail it provides. A BIM is therefore a "computer interpretable digital description" of physical and functional characteristics of a facility. BIM models contains not only the geometrical information, but also many other information about the building. Since computers can interpret information, BIM enables virtual modelling for many domains such as energy modelling, safety modelling, and cost modelling. The software industry produces numerous tools for building practitioners to work in a convenient interface (e.g. 3D graphical for Architects) while communicating with (reading from and writing to) BIM in software backend.

3. BIM SOFTWARE

The term "BIM Software" may often become misleading. It cannot be construed in the same manner we used to understand "Draughting Software". Any draughting software had common feature that computer screen was a "drawing sheet" on which the drawings were created with lines and curves using common input methods available for computers. In contrast, a BIM Software is not a single type; it can be any computer tool that works BIM data format. Within this scope, even a spreadsheet application like MS Excel may become a BIM Software by use. Thus, a simplified definition is; BIM Software is computer software used to automate or support managing, modelling or visualising of BIM data. However, it is often the software used for modelling that is talked about under BIM Software.

Wide variety of BIM (or BIM compatible) software applications have been developed during the past two decades. Autodesk Revit, Bentley Architecture, Graphisoft ArchiCAD, Tekla Structures, Innovaya Visual BIM, Vico Estimator, Exactal CostX, Autodesk Navisworks, Solibri IFC Model Checker, and Synchro are among the popular applications. While some of them are for modelling, others are for reading the models for optimising, costing and scheduling. The following list of factors affecting the choice of software were expressly or impliedly had been identified by number of authors who discussed about BIM adoption (viz. Arayici *et al*., 2011, Khemlani, 2012, Won and Lee, 2010, Luthra, 2010, Gunasekara and Jayasena, 2013, Eastman *et al*., 2011).

1. Modelling and viewing capabilities of application
2. Accuracy of data in models
3. Sharing capability of models
4. Information documenting capabilities
5. Spread of usage or popularity of application
6. Affordability

This list provides a checklist and also can act as the framework for selection of suitable software applications.

3.1. MODELLING AND VIEWING CAPABILITIES OF APPLICATION

In selecting an application, emphasis is given on the features of the application and the ease of using them. Features can primarily be divided into two areas as (1) Model Viewing, and (2) Model Authoring. Model viewing includes ease of navigation around the model, filtering for object types and properties, and computed information such as areas and volumes. While authoring may primarily understood as 3D (3 dimensional) modelling, it also includes modelling with other parametric information such as materials, thermal properties and costs. Since the value of BIM becomes significant in large and complex projects, scalability is often considered to be of high importance.

3.2. ACCURACY OF DATA IN MODELS

Parametric accuracy of data in the model is a key advantage of BIM technology. However, accuracy of the data in the model depends on the input accuracy. Thus, ability given by the application for the user to input data accurately is an important aspect. Often talked about feature under this is "dimensional accuracy". Another concern is the accuracy of data exchanged between parties, which is in fact related to sharing capabilities of models authored.

3.3. *Sharing Capability of Models*

Sharing capability may relate to the ability to issue BIM data to other parties in Temporary Multi Organisation (TMO). This arises from application's capability to import from and export to various file formats used by others (e.g. ifc, dxf, gdn, dwg, skp, pdf etc.). Capability so defined may not be nominal, accuracy of data in such exchange is crucial. Alternatively, sharing capability may be construed as the ease of multiple parties working in the same model. Either way, it is about the multidisciplinary capability of the system in use.

3.4. *Information Documenting Capabilities*

Documenting capabilities of the software can vary on the type of application. In general, this refers to the capability of generating fixed exports necessary for construction and contract documents. Primary features includes export of models to 2D and 3D PDF (Portable Document Format), information and schedules to PDF, spreadsheet of document formats and direct printing. The features are enhanced by ease of setting up drawing sets, schedules, standards, templates. This also includes the ability to generate photo realistic renderings and animations

3.5. *Spread of Usage or Popularity of Application*

The spread and popularity of an application or vendor indicated by its market share in the region is often considered by the fresh adopters, and they usually favour them. While the most popular may not be the best in terms of capabilities, it generally offers ease of adoption since object types and libraries, and skills and knowledge for use and troubleshooting are likely to be widely available. In addition, it will help positioning the adopter among other major competitors. Therefore, the selection should not simply be the popular choice, but an informed judgment.

3.6. *Affordability*

It is the affordability what matters at the final decision. However, it does not limit to the initial software cost (which includes licence and training), but also includes hardware, network upgrade and running costs. The running costs include user support, trouble shooting, server management, hardware maintenance and licence renewal (or subscriptions). Employee turnover cost will also be high as more orientation and training will be required. Thus the availability of user support, tutorial and manual, and the learning curve of applications are also of primary concern.

4. BIM Software Environment

In absence of a national initiative, a bottom up approach for BIM implementation is suitable for Sri Lanka. Currently, there is no known initiative at any Sri Lankan organisation to adopt BIM. In this context, it likely that a client demands for BIM will be the strongest short-term enabler for BIM in Sri Lanka. How would the TMO respond to such demand? Will the varying types of software used by individual party in TMO support BIM? If not, how easily will they able adopt compatible software? These may be the questions one would ask; but in fact the answers to these depend on what BIM Software Environment is used.

In general, identifying the software used for authoring (modelling) in BIM implementation helps to understand the work arrangement and possibilities. For example, if Autodesk Revit is used for architectural modelling, it is generally preferred that other members of the team use Autodesk products or software supporting exchange of data in DWFx file format. Since there is however a large number of BIM authoring software, analysing them individually under each of the factor above is not the way forward.

The BIM Software Environment (BIMSE) has two aspects of concern.

1. Software Operating Environment, and
2. Runtime Environment

The Software Operating Environment or the Integrated Application Environment is about the environment in which the users run Application Software. Operating Environment (OE) is not synonymous to Operating

System (OS). OE is form of middleware that rests between the OS and the application. For BIM implementation, it is primarily related to the interface the users interact with BIM.

The Runtime Environment (RE) executes the activities of a computer language used in software environment. RE is what programme language uses to invoke various functions in a computer. For the spatial issue of the study (i.e. BIMSE), RE relates to the efficiency of interaction between (among) different software applications.

For the purpose of the study, analysis of core technological aspects is not necessary; instead, it demands the review of the practical implications of the technology. For ease of comprehension, a classification of BIMSE is helpful. The basic classification based on data model as (1) homogeneous software environment, and (2) Plural Software Environment identifies two widely different approaches to set up BIMSE for a BIM based project implementation. Table 1 presents a comparison between these software environments.

Table 1: Homogeneous and Plural Software Environments - Comparison

Criterion	**Homogeneous Software Environment**	**Plural Software Environment**
Data sharing platform	Central data repository	shared or central data repository
BIM Software	Proprietary applications/suites – Forced to select the same software by all collaborating parties. Cost of software is high and license sharing capability varies.	Bespoke middleware created for IFC based applications – Collaborating parties are free to choose own software tools to achieve higher performance in their AEC tasks
Data exchange	primarily based on file formats that depend on the selected software	primarily based on IFC data model
Data amalgamation/ Data fusion	Performed via live synchronisation of data. Data duplication is possible	Performed via model fusion with fusion algorithms Data duplication is possible
BIM software modelling expertise	All team members require equal expertise	All team members do not require equal expertise when using reference models and IFC
Selection of project partners	Focus on the competency of a specific BIM software tool may overlook the actual competency in performing engineering tasks.	The use of reference model concept with IFC reduces the needed competency in BIM, there by maintaining the requirement of actual competency in performing engineering tasks.

Source: Gunasekara and Jayasena (2013)

The key feature of Homogeneous Software Environment is that one software (or more often a suite of software from one vendor) is selected to be the primary tool. Most such software (or vendor of the software) comes with a "server module" to act as the central data repository; alternatively, the primary software itself may have the built-in facility for this (refer Autodesk, n.d., Bentley, 2014, Graphisoft, n.d.). Working in these types of Software Environments offer live synchronising of all data among model contributors. The ownership of the elements of each contributor is flagged in model. Modification of an element by a different user than the original owner results in a duplication of the element in the model with a new flag. However, real-time synchronisation is not often preferred in the industry and they usually set it to manual or periodical (hourly/daily/weekly) synchronising primarily due to hardware (including network) limitations.

It is beneficial to construe the BIM working environment using the concept of "BIG BIM, little BIM" as described by (Jernigan, 2008). The BIM within the influential boundaries of a company is "little BIM". The

BIM beyond the boundary is "BIG BIM". This occurs when a TMO is established for a project. In this context, BIG BIM represents the Central Data Repository, which is the Central Model in the native format of the selected Homogeneous Software Environment. The project partners (i.e. the members of TMO), will have to match their in-house software to support selected BIG BIM software environment. The practical approach would be to select the partners who can match their little BIMs to selected Software Environment.

An extension to this is that most proprietary systems have exchange formats for which supports the software from other vendors. For example, the Quantity Surveyor (QS) need not implement a software supporting native format. Instead they would use a QS specific software which supports exchange format of the selected Software Environment (Exactal, 2012). The drawback of this method is that exchange format may not include all necessary data.

Figure 2 graphically illustrates the Homogeneous Software Environment. Data sharing is shown for entire design and construction lifecycle where builder's as built model data is also shared with the architect. Engineer in the figure represent all different types of engineers involved in the project. It should be noted that this representation does not account contractual requirements. Certain exchange of data shown may not become contractually proper depending on the contractual arrangement.

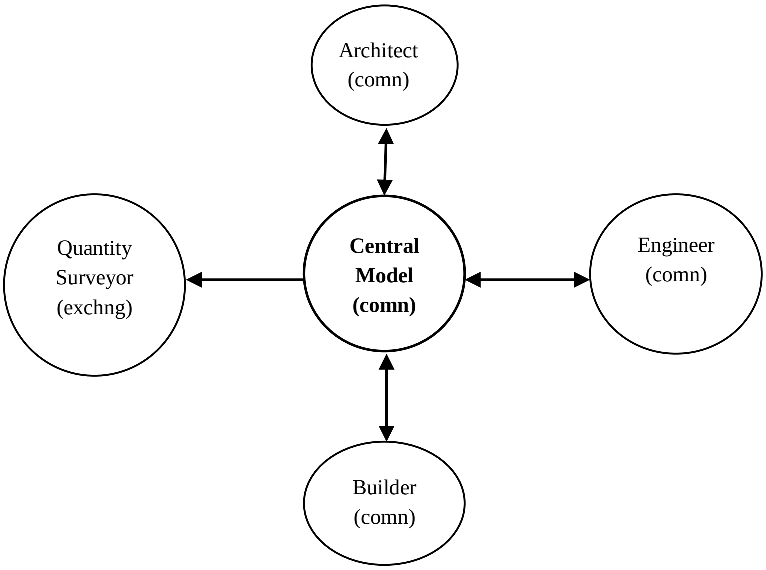

Figure 2: Data Exchange in Homogeneous Software Environment

Plural Software Environment relies on open standard IFC for data exchange. The traditional practice has been the model sharing; i.e. the native model is exported to IFC by the software, and this IFC model is sent to the other partners for further development and modification. Received IFC files are often converted to native format of the software they use for further authoring, and once done exported to IFC format to share with other partners. The software supports updating the current internal native model with the received IFC data to incorporate the development from other partners.

Illustrating the above with example, an Architect uses Archicad and models in its native format. She exports it to IFC to share with engineers. The Structural Engineer receives it and imports it to Tekla Structures native format and performs the structural modelling. It should be noted that IFC does not contain all data available in Archicad native model, but a set of predefined data that has been identified as necessary and satisfactory for collaborative working. What data is to be exchanged is defined by Model View Definition (MVD: refer buildingSMART alliance, n.d. for more informaton). Once done (to a level that he is ready to share), the Structural Engineer will export his model to IFC (note that this will not contain all data in his native model) and share with others. On receipt of it, the Architect, Electrical Engineer, HVAC Designer, etc. updates their native models with new data in received IFC.

The practical methods of data sharing in traditional practice of Plural Software Environment are shown in Figure 3. The figure should be construed by referring the generic description given for Figure 2 above.

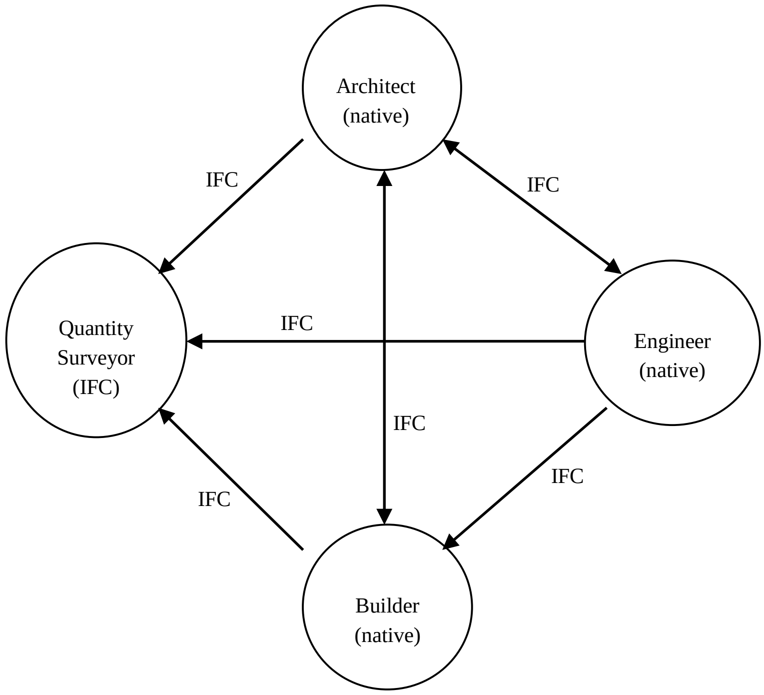

Figure 3: Data Exchange in Plural Software Environment

A successful experimental case of using Central Data Repository (based on IFC data exchange) in a Plural Software Environment has been reported by van Berlo *et al*. (2012). They used open source BIM server (refer BiMserver, n.d.) for their experiment. They share that "it is true that IFC will not contain the full dataset of the original, native data-base from the source software, but often the receiving user does not require all details. Occasionally some data became unreliable (objects are misplaced or gone) during import, but the overall quality of contemporary implementations was considered satisfying. The imported data is used as a reference during engineering. For example the MEP engineer uses some data from the structural engineer to design the location of the piping. The piping is not added to the original dataset of the structural engineer, but exported to IFC as a new dataset that is send to the central data repository" (van Berlo *et al*., 2012). Thus it is likely that the use of Central Data Repository in a Plural Software Environment is a practical reality.

5. ANALYSIS AND SYNTHESIS

While it has been popular for many to adapt Homogeneous Software Environment initially, the latest survey by National Building Specification UK (NBS, 2014) shows significant use of Plural Software Environment in BIM matured industries. However, BIM maturing and infant industries are likely to prefer Homogeneous Software Environment offered by software vendors as proprietary solutions due to accompanied customer support including structured learning resources. However, it is important to review such preference also in terms of overall effectiveness.

BIM practices are not totally alien to the Sri Lankan construction industry. Though there are no clear reports, it is known that BIM capable software such as Revit, Archicad and CostX being used by some in the industry. However, these uses are not in BIM based project environment, but used as in-house tools to generate non-BIM information such as 2D drawings and 3D graphics.

Multiparty collaborating using a central model may not be readily acceptable for the industry participants. Members of TMO will prefer to use private repositories (or models) to keep their unshared data within the little BIM, and as the design (or model) develops exchange the permissible data with the BIG BIM (Nour, 2009). Ideally, the software tools must be selected based on the tasks performed by the member, but not on the ability to share data with others. Accordingly, it is likely that a Plural Software Environment to be the most favoured solution for Sri Lankan industry.

In an industry of a developing economy, affordability will be a significant factor in selection of software applications. Plural Software Environment will allow the flexibility, and the increasing support for IFC with the development of free and/or open source software will make the technology affordable for participants with limited affordability (budget constraints).

It is not necessary that all data is available for everybody to perform good collaborative AEC project; but what is important is that all necessary data for each partner is available. The data that is shared by other partners shall be exchanged via BIG BIM; private data can reside in their own repositories. There is no requirement that a model is exchanged via few software tools using IFC (i.e. import and then export by one software to another) to contain all data it has in the first model. Therefore, it is unwise to be misled by the concept of "round tripping" which is discussed by some authors highlighting that some information is lost during the trip. However, the consistency of information during the trip is critical for interoperability.

There can be limitations in using IFC but these may not become significant barriers if the limitations are understood and accounted for (Bazjanac and Kiviniemi, 2007). The experiment of van Berlo *et al*. (2012) was before the release of IFC4 which should be better than IFC3 (IFC4 is described in detail in Liebich *et al*., 2013). Powerful free to use IFC model viewers such as Solibri Model Viewer (Solibri, n.d.) provides anybody to access any information in IFC data models through a user friendly graphical interface. Thus the use of IFC is unlikely to cause issues in dissemination of information to downstream.

6. CONCLUSIONS AND RECOMMENDATIONS

The synthesis of current knowledge from literature combined with generic knowledge about the Sri Lankan context shows that Plural Software Environment likely to be the preferred solution for Sri Lankan context. It will offer the flexibility for participants to select the software tools for their requirements, preference and affordability. Open source BIM Server, which is freely available, is recommended to be used as the central data repository. Implementation will obviously require the support of Information Technology Experts.

Initial adoption may become very much challenging due to required changes in practices (not much influenced by BIMSE), and cultural and legal barriers which were not considered in this paper. These aspects are also to be reviewed in decision making regarding adaption of BIM.

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CARBON LABELLING SCHEME FOR CONSTRUCTION PRODUCTS: THE BENCHMARK FOR LOW CARBON MATERIALS

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ABSTRACT

Climate change has become a global threat with worrying consequences for many countries. Among various economic sectors, the construction industry consumes 40% of materials entering the global economy and generates significant amounts of greenhouse gases (GHGs) - the main cause of climate change. Particular attention should be attributed to the embodied carbon of construction materials as it could contribute to 70% of GHG emissions at the construction stage and up to 25% of a building's life time energy consumption. It is thus highly desirable to select and use low carbon construction products so as to minimise the GHG emissions arising from the construction industry. In view of this, the Construction Industry Council (CIC) in Hong Kong has initiated a Carbon Labelling Scheme for Construction Products as part of its mission to promote green building practices and sustainable development. This paper introduces the carbon assessment framework of the Scheme, including the product categorisation, principles and system boundary of carbon footprint quantification, benchmarking mechanism, and certification process. The paper also presents the methodology of developing a GHG quantification tools for assessing carbon footprint of products (CFP). As a voluntary scheme in Hong Kong, itaims to provide verifiable and accurate information on the carbon footprint of construction products for industry practitioners to select 'low carbon' materials.

Keywords: *Carbon Footprint; Carbon Labelling; Construction Products; Sustainable Development.*

1. INTRODUCTION

The construction industry accounts for large amount of greenhouse gas (GHG) emissions by consuming great quantity of energy and resources. According to the Hong Kong Ecological Footprint Report 2010 issued by the World Wide Fund (WWF), the construction sector is the second largest contributor to the Hong Kong's carbon footprint in the year of 2007 (WWF, 2010). In response to the Hong Kong Special Administrative Region (HKSAR) Government's carbon reduction target of reducing the carbon intensity by 50-60 percent by 2020 on the basis of 2005 levels, the construction industry has an indispensable role to play.

During the years of the life cycle of construction facilities, GHG emissions are associated with the full life cycle stages: resource extraction, construction materials manufacturing, materials transport, on-site construction, operation and maintenance, and demolition. Researchers and industry practitioners normally pay more attention to the emissions released during the user stage of the construction facility or in maintaining the inside environment through processes like heating and cooling, lighting and operation appliances since these stages consumes much energy over years of usage. However, the carbon embodied in a construction facility should also be concerned as it is hardly to mitigate the embodied carbon once the construction is completed (Monahan and Powell, 2011). Fieldson *et al.* (2009) stress that embodied carbon of construction materials shares a significant portion of the building's life cycle emissions (Figure 1). Therefore, selecting low-carbon materials in the early project stage is highly desirable.

In Hong Kong, the recent strong growth in gross construction volume, together with the ten major infrastructure projects, will continue to drive up the demand for construction services and materials.

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This makes the low carbon construction materials become a pressing demand of local market. However, Hong Kong does not have an authoritative, independent and publicly acceptable evaluation system providing the benchmark of the locally used construction materials. Industry stakeholders are thus calling for a recognised evaluating system indicating the performance of each commonly used construction materials.

In view of this, the Construction Industry Council (CIC) has initiated a research project to develop a Carbon Labelling Scheme for Construction Products (the "Scheme"), as part of the CIC's mission to promote green building practices and sustainable development. The Scheme aims to provide the communication of verifiable and accurate information on the carbon footprint of construction products for client bodies, designers, contractors and end users to select 'low carbon' materials. This paper introduces the carbon assessment framework of the Scheme, including the product categorisation, system boundary of carbon footprint quantification, benchmarking mechanism, and certification process. The current implementation progress and future prospects of the Scheme will also be highlighted.

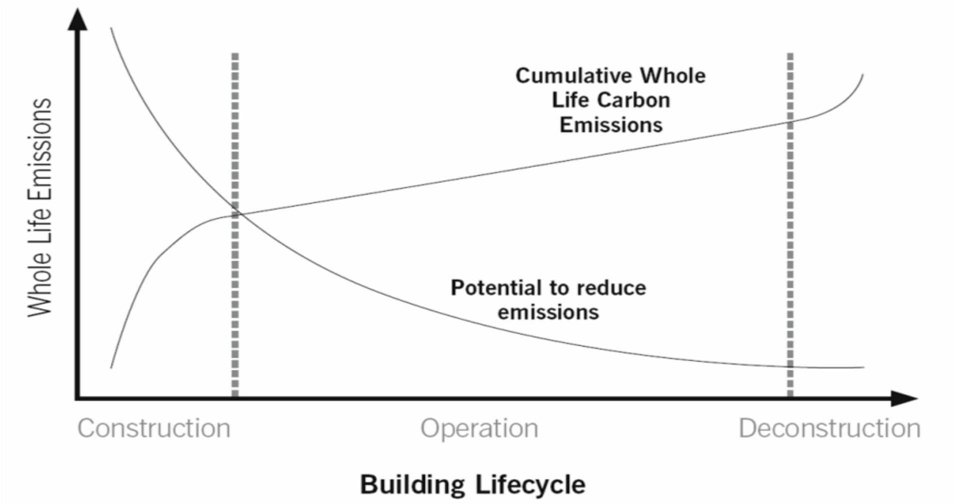

Figure 1: Potential of Reducing Whole Life Emissions during Building Life Cycle
Source: Fieldson *et al.* (2009)

2. CARBON ASSESSMENT FRAMEWORK

2.1. SCOPE AND PRODUCT CATEGORISATION

The Scheme focuses on a single impact category: climate change by quantifying the GHGs generated from the certain life cycle stages of construction materials in terms of carbon dioxide equivalents (CO_2e). It covers the six types of GHGs under the Kyoto Protocol (United Nations, 1997), namely, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) which impact directly on global warming. Other environmental aspects along the product's life cycle are beyond this labelling Scheme.

Among various types of construction products, the Scheme initially covers the most commonly used construction materials with relatively high GHG emissions to the industry. Cement is extensively used in the construction industry as an essential ingredient in producing concrete. As the production of cement consumes large quantities of fuel and reacts with chemicals under high temperature during manufacturing, especially the kilning process, the cement industry alone generated approximately 5% of the global anthropogenic CO_2emissions (IPCC, 2001). The production of steel products is energy intensive and the iron and steel industry is responsible for about 10% of worldwide CO_2 emissions from fossil fuel use (IEA, 2008), which also accounts for about 5% of the global GHG emissions. Therefore, cement and steel (rebar and structural steel) are covered under the labelling system of the Scheme at the outset.

In accordance with BS EN 197-1:2000 "Composition, Specifications and Conformity Criteria for Common Cements", the CEM I - Portland cement (all strength classes) is the specific type that being evaluated under the Scheme. Portland cement is composed of 90-95% clinker and up to 5% of minor additional constituents. Other types of cement products may be added to the scope of this Scheme in due course.

As for steel products, Non Alloy Steels in accordance with BS EN 10020:2000 "Definition and Classification of Grades of Steel" is covered under the Scheme. It contains by mass more iron than any other single element, having carbon content generally less than 2% and containing other elements. It is applicable to four broad steel product categories that are commonly used in the construction industry namely, (i) steel reinforcing bar; (ii) steel section; (iii) steel plate; and (iv) steel pipe as shown in Table 1.

Table 1: Product Categorisation of Steel under the Scheme

Product Category	**Product Sub-Category**
I. Reinforcing bar	-
II. Steel section	a. Structural section (incl. Universal beam / column, H section, I section, Bearing pile) b. Hollow section c. Bar section (incl. Flat bar, Square bar, Round bar, Tee bar) d. Others (Channel, Angle, Z section, Mesh)
III. Steel plate	-
IV. Steel pipe	-

The quantification and reporting of the CFP under the Scheme is based on a life cycle assessment (LCA) as detailed in ISO 14044:2006. The carbon footprint assessment should therefore include the four phases of life cycle assessment (LCA), i.e. goal and scope definition, life cycle inventory (LCI) analysis, life cycle impact assessment (LCIA), and life cycle interpretation.

2.1. SYSTEM BOUNDARY

For a construction material, the full life cycle starts from the resource extraction, construction materials manufacturing, transport, on-site construction, operation and maintenance, demolition, and ends at disposal and recycling (Hammond and Jones, 2008). However, it is not recommended to estimate the full life cycle carbon emission of construction materials because the emissions in the use phase are insignificant, and the emissions from the disposal stage are difficult, if not impossible, to predict. With little manufacturing industry, Hong Kong imports large amount of construction materials from other regions, which makes the transport of material becoming a potential significant source of GHG emissions. The framework of the Scheme is thus determined as "Cradle to Site" that covers the raw material acquisition, manufacturing, transport until the material reaches the boundary of Hong Kong (Figure 2).

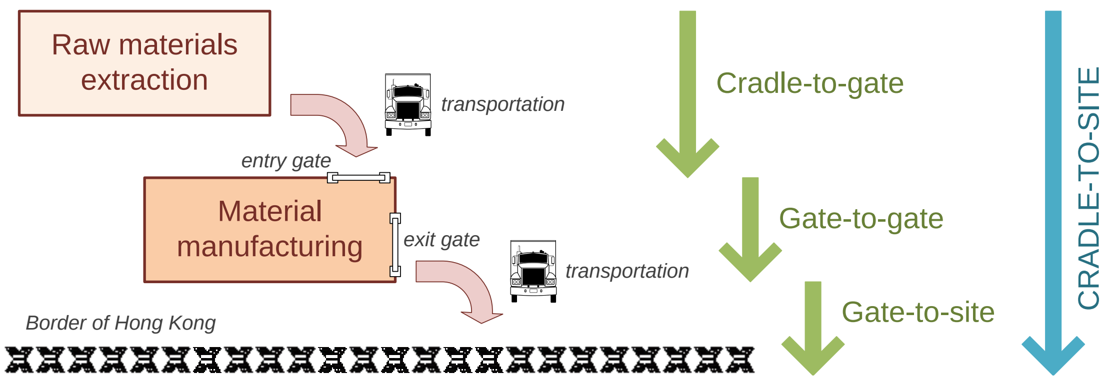

Figure 2: A Cradle-to-Site System Boundary

According to ISO Technical Specification 14067:2013, all the direct and indirect GHG emissions attributed by the processes within the system boundary should be accounted for the carbon footprint of the selected material under the Scheme, including fuel combustions, chemical reactions, energy use, loss to atmosphere of refrigerants and other fugitive greenhouse gases, process operations, service provision and delivery, land use and land use change, waste management, etc. Specific to the cement and steel respectively, the process and source of GHG emissions can be summarised as the following Tables 2 and 3.

Table 2: System Boundary for Quantifying Carbon Footprint of Portland Cement

System Boundaries	Processes
I. Upstream Processes	• Extraction and production of raw material and energy wares used in the production and packaging of the finished product • Transportation of raw materials and recycled materials to the plant • If relevant, recycling process of recycled materials used in the product
II. Core Processes	• Production of raw meal • Production of clinker (calcinations) • Grinding of cement • Storage and packaging for dispatch
III. Downstream Process	• Transportation from manufacturing to the border of HK

Source: EPD® (2010)

Table 3: System Boundary for Quantifying Carbon Footprint of Reinforcing Bar and Structural Steel

System Boundaries	Processes	
I. Upstream Processes	• Extraction and production of raw material and energy wares used in the production and packaging of the finished product • Recycling process of recycled materials used in the product • Transportation of raw materials and recycled materials to the plant	
II. Core Processes	• Production of steel including processes in: ➢ Coking plant ➢ Sintering plant ➢ Pelletising plant ➢ Blast furnace ➢ Basic oxygen furnace ➢ Electric arc furnace ➢ Ladle furnace ➢ Reheating furnace of rolling mill	• Finishing of steel ➢ Casting ➢ Hot rolling ➢ Cold rolling ➢ Storage and packaging for dispatch
III. Downstream Process	• Transportation from manufacturing to the border of HK	

Source: EPD® (2011)

Following the "Cradle to Site" approach, the GHG emissions and removals in the use stage are neglected. As for cement, the irreversible nature of cement products justifies the exclusion of the end-of-life stage. In addition, recarbonisation of cement and concrete is not covered due to lack of accurate and quantifiable data. For steel products, the emissions from the process of recycling steel, if any, is estimated in the upstream process rather than the disposal stage.

2.2. GHG EMISSION SOURCES

The GHGs generated from all unit processes as included in the pre-defined system boundary should be quantified and reported in the assessment of the carbon footprint of product (CFP). The emissions can be divided into direct and indirect GHG emissions. The direct emissions stem from sources that are owned or controlled by the material supplier, whereas the indirect emissions originate from sources that are controlled by third parties, but they are nonetheless related to the activities of the material supplier (Cement Sustainability Initiative, 2011).

The labelling scheme was developed based on the ISO/TS 14067:2013 "Greenhouse Gases – Carbon Footprint of Products – Requirements and Guidelines for Quantification and Communication". The GHG assessment frameworks of the cement and steel products were established with reference to the "CO_2 and Energy Accounting and Reporting Standard for the Cement Industry" issued by Cement Sustainability Initiative (CSI) in 2011, and the "Calculating Greenhouse Gas Emissions from Iron and Steel Production: A Component Tool of the Greenhouse Gas Protocol Initiative." issued by The GHG Protocol Initiative (2008), respectively. Looking into details of the GHG emission sources of cement and steel over the "Cradle to Site" life cycle stages, the sources could be summarised and categorised as presented in Table 4. One of the major sources of direct emissions is the combustion of fuels, which are burned in either the kiln of cement production or the furnace of steel manufacture. For non-kiln/furnace fuels, they are normally applied for the following usages:

- Quarrying / mining raw materials
- On-site transportation
- Equipment
- Room heating / cooling
- On-site power generation

In the Portland cement production, another major direct emission source is the chemical reaction in the calcinations process, where limestone is calcinated under high temperature (around 1,450°C) and CO_2 is largely emitted contributing 60-65% of total CO_2 emissions in the cement processes (IEA/WBCSD, 2009). On the other hand, steel production also involves some special industrial processes where chemicals containing carbon are burned or decomposed to release CO_2 and CH_4.

Key indirect GHG emissions arising from the production of cement, reinforcing bar and structural steel products include four common categories: i) the GHGs associated with the external electricity consumption; ii) the production of bough materials and energy wares; iii) transportation for raw material and products delivery; and iv) land use change.

Table 4: GHG Emission Sources of Portland Cement and Steel Products under the Scheme

	Direct Emissions	**Indirect Emissions**
Portland Cement	• Raw material calcinations and combustion • Combustion of kiln fuels • Combustion of non-kiln fuels	• External production of electricity consumed by cement manufacturers • Production of bought raw materials, energy wares and clinker • Off-site transportation • Land use change
Steel Products	• Combustion of furnace fuels • Combustion of non-furnace fuels • Industrial processes ➢ Sinter production ➢ Lime production ➢ Steel production ➢ DRI production ➢ Flaring	• External production of electricity consumed by steel manufacturers; • Production of bought raw materials and energy wares • Off-site transportation • Land use change

2.3. BENCHMARKING MECHANISM

After quantification, the results of the CFP of the material should be documented and reported in accordance with certain criteria as required by relevant international standards: ISO/TS 14067:2013; ISO 14040:2006; ISO 14044:2006 and ISO 14025:2006.

The reported CFP of the material is then evaluated and differentiated according to the benchmarking against the emissions of the same category of construction material. The Scheme adopts a five-level multiple benchmarking regime as shown in Figure 3. E_m refers to the submitted carbon footprint of product (CFP). E_{da} refers to the average carbon emission value. E_{da} is currently determined by obtaining relevant values from international recognised inventories, such as Ecoinvent, U.S. LCI, Japan CFP Database, WBCSD CSI database, etc. In the long run, the benchmarks would be reviewed and adjusted on a regular basis, and will be adjusted using local data if sufficient data are obtained as the Scheme develops.

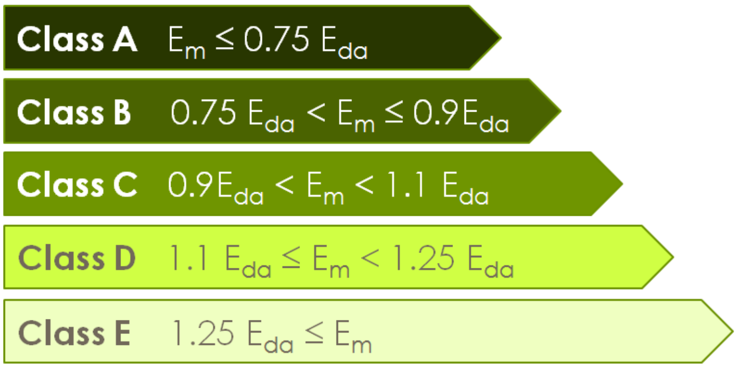

Figure 3: Benchmarking Mechanism of the Scheme

2.4. CERTIFICATION PROCESS

As a voluntary carbon labelling system, the certification of the Scheme should follow the communication criteria as stated in the ISO/TS 14067:2013 and the ISO 14025:2006 for Type III Environmental Declaration. This requires the involvement of the independent validation and verification by a third-party body (VVB). In addition, carbon assessment is still novel in Hong Kong and the potential applicant organisation itself may lack the competent professionals to conduct carbon audits specifically for construction materials. This leads to the engagement of certified carbon auditor (CCA) for a particular product category under this Scheme. The engagement of CCA and VVB in the certification is to make sure that the applied material's carbon footprint is correctly, accurately and completely audited, reported and verified. A complete procedure of certification process is presented as below in Figure 4.

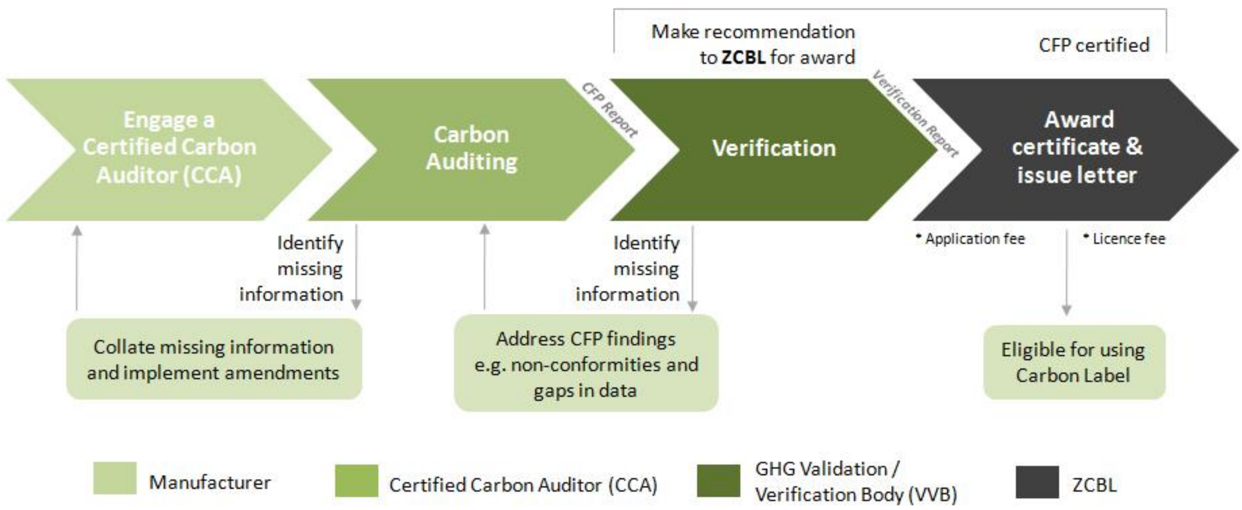

Figure 4: Certification Process of the Scheme

3. IMPLEMENTATION OF THE SCHEME

Based on the developed carbon assessment framework and tremendous preparation work, CIC formally launched the Scheme in late 2013 and now it is open for application.

A set of Assessment Guide and Quantification Tool has been developed for cement and steel, respectively (refer Figure 5 and Figure 6). The Assessment Guide details principles, requirements and rules for the quantification and reporting of the carbon footprint of products (CFP) under the Scheme. With the embedded equations and built-in emission factors, the Quantification Tool provides the applicants a user-friendly tool for data input and results auto-generation. Material suppliers can prepare their product specific carbon inventories using the CFP tool following the guidance of the Guide.

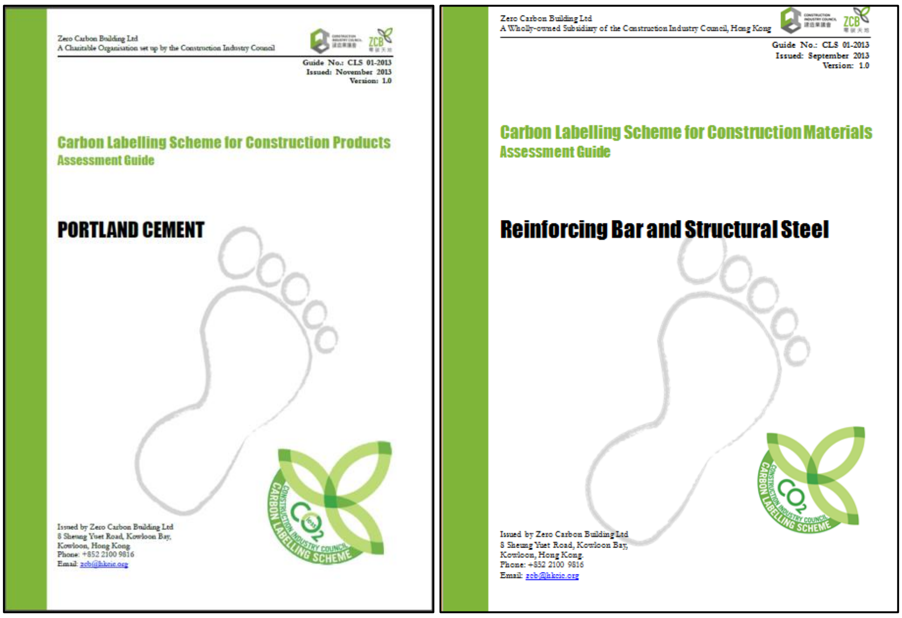

Figure 5: Assessment Guides

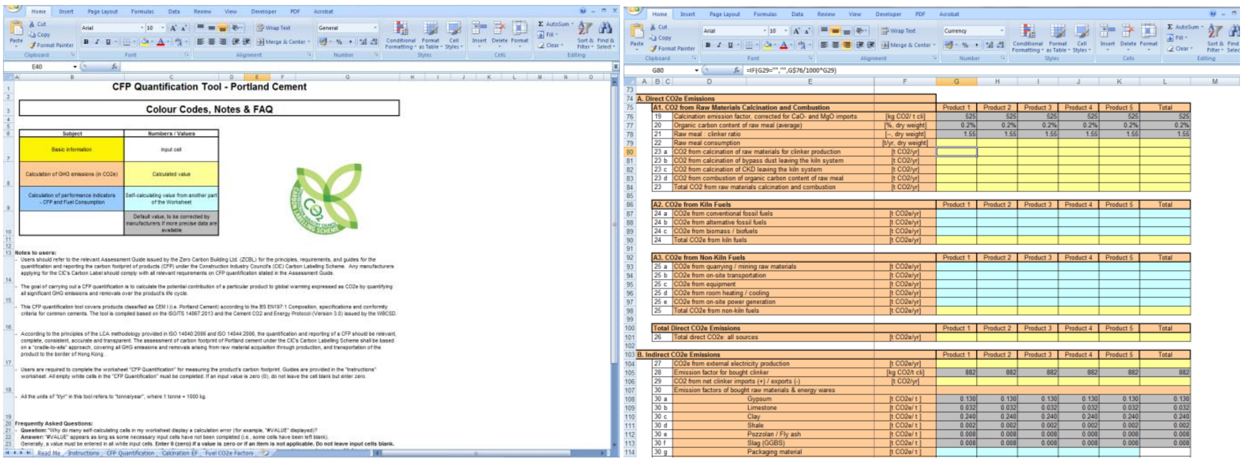

Figure 6: CFP Assessment Tool

For the effective implementation of the Scheme, CIC has carried out a series of proactive strategies including organising seminars, workshops and training programmes to provide basic knowledge on the Scheme and professional trainings on carbon auditing, liaising with relevant industry stakeholders for promotion of the Scheme, launching the online listing service for labelled materials, etc. In addition, CIC is working towards integration of the Scheme into the Hong Kong green building assessment model (BEAM Plus), with which the incentive would encourage developers and designers to consider applying low carbon construction materials with an outstanding grade under the carbon labelling scheme to achieve a good

BEAM Plus classification. More importantly, CIC is lobbying the government agencies and large developers to incorporate the Scheme into their tender assessment, which could further affect the procurement of the contractor and stimulate the market demand of the labelled materials.

4. FUTURE PROSPECTS

The Phase II Research on this project has commenced in early 2014, which develops carbon quantification frameworks for additional 10 construction materials to extend the coverage of the Scheme. For long-term development, the Scheme will not only focus on Hong Kong market but also expand to Asian regions. In order to further enhance the international visibility of the Scheme and attract attention of material manufacturers overseas, CIC will explore various channels to introduce and promote the Scheme. In the long run, CIC will seek support from other relevant organisations, associations and institutes for information sharing to expand the coverage of the promotion. It is expected that the Scheme will be widely recognised by the industry by achieving the incorporation of the Scheme into Beam Plus system, as well as providing incentives in the government procurement plan.

5. CONCLUSIONS

This paper reports a project on developing and implementing the Hong Kong-based Carbon Labelling Scheme for commonly used construction materials. The development of the carbon assessment framework under the Scheme was introduced in the paper, including the coverage of the materials (i.e. cement, rebar and structural steel) in the initial stage of the Scheme and the product categorisation of cement and steel products, the “cradle-to-site” system boundary and the associated GHG emission sources within the system boundary, the benchmark mechanism for grading and differentiating the performance of each material, and the certification process for issuing the carbon label. Based on the outcome of the research, the CIC implements the carbon assessment framework to the industry by launching the Scheme formally in late 2013 with user-friendly assessment guide and calculation tool provided. A series of promotion strategies have been carried out for the smooth implementation of the Scheme. It is anticipated that the continuous development of the Scheme will help the industry stakeholders build strong awareness on carbon footprint and low carbon construction, thus facilitating green building practice and sustainable development of the construction industry as a whole. As a Hong Kong-based voluntary scheme, the CIC Carbon Labelling Scheme for Construction Products intends to encourage the demand for, and supply of, low carbon products, thereby contributing to Hong Kong's transition to a low carbon economy.

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CONCEPTUAL FRAMEWORK FOR UNDERSTANDING CONSTRUCTION PROJECT CULTURE: A LITERATURE REVIEW

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ABSTRACT

Complex human behaviours and thoughts bound by the complex construction activities have made the topic "construction project culture" an ambiguous area in the construction management literature. Despite of a several few attempts, definition of the construction project culture still remains as an area to be unveiled. This paper attempts to provide a conceptual framework for understanding construction project culture by highlighting few questions to be answered in the process of defining a project culture. The initial question raised is; 'what cultural manifestations in deed represent construction project culture?' next; 'how does construction project culture exists: its structure?' and, finally; 'how does construction project culture emerges?'. These questions have been answered by an extensive literature review emphasising; underlying assumptions to give the true representation of construction project culture which is structured in sub-cultural groups that could be analysed in integrated, differentiated and fragmented perspectives and arguing its emergence to be with the project team efforts of answering internal integration and external adaptation problems of the project team itself. Further research of this paper will aim developing methodological frameworks to carry out empirical studies to answer the highlighted research questions and to bring empirical evidence to what the construction project culture is.

Keywords: *Construction; Project Culture; Project Team.*

1. INTRODUCTION

Construction literature provides several attempts in defining construction project culture. Zuo and Zillante (2005, p.357) defines construction project culture as; "the shared values, basic assumptions and beliefs that the participants involved in a project hold that determine the way they process the project and the relationship with each other in the project environment." This definition goes in line with the definition of culture given by Hofstede (2011, p.3) in generic terms as; "the collective programming of the mind that distinguishes the members of one group or category of people from others" and organisational culture as; "the way people perceive what goes on in their organisational environment". However, Martine (2002) argues against studying culture as a shared phenomenon as has done by Hofstede (2011) and Zuo and Zillante (2005). Martine (2002) states that cultural studies in depth would not exhibit consistency. According the Martine (2002), shared culture is brought in only a part of culture which most of the times created by a top level member of an organisation or a group vesting power on the other members of the group where this top level members would be an unrepresentative sample of a given culture. This brings in the problem whether shared culture is still valid with the construction project culture.

The next problem with the aforementioned definitions was that those include many cultural manifestations such as beliefs, values and assumptions in the definition of project culture with reference to construction. Ankrah *et al*. (2009) discussed the artefacts or the cultural form in understanding culture at project level in construction setting. Further, Marrewijk (2006) in the elaboration of the two cultural episodes in Evinron mega construction project, uses the classification of cultural manifestations of Martin (2002); cultural forms, practices and content themes. However, at conclusion drawing, Marrewijk (2006) only refers to the content themes - specifically value orientations of the two episodes to elaborate the culture. This gives the

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notion that cultural forms and practices do not provide the ultimate definition of a project culture. Schein (1984) depicts that to really understand a culture and to establish more completely the group values and explicit behaviour, it is vital to dig into the underlying assumptions, which are really unconscious but which actually determine how group members perceive, think and feel. Therefore, this gives rise to the problem which really depicts construction project culture out of the number of cultural manifestations available.

Zuo (2008) brings in the definition stated by Zuo and Zillante (2005) to develop a framework to understand construction project culture. This model includes some cultural dimensions related to the way participants process the project and the relationship between participants in the project environment. It is because, Zuo (2008) argued culture to emerge as the way the project participants process the project and the relationship with each other in the project environment. However, the model of construction project culture proposed by Zuo (2008) does not discuss the cultural aspect of "power", which is one of the most important contributor to the culture as discussed by Schein (1983) related to the internal and external problems that shape-up the culture of a group. Even the model by Zuo (2008) is only relevant to relational types of contracts. In contrast, Ankrah *et al*. (2009) state that different procurement routes do not result in different cultural orientations. In addition, Ankrah *et al*. (2009) bring in some factors affecting the construction project culture which are worth looking into in the process of defining a project culture. Therefore, this raise the problem how construction project culture actually emerges.

Hence, this paper intends to bring in literal analysis and arguments to answer the questions:

1) What cultural manifestations in deed represent construction project culture?
2) How is the construction project culture organised?
3) How does construction project culture emerges?

Finally, a conceptual framework for understanding construction project culture would be presented.

This paper is structured in six sections, initially the complexity of culture in construction is explained and then, cultural manifestations of construction project culture are discussed. Next, an insight into the project culture through a discussion of its components and structure is presented. Thereafter, attention is drawn to how construction project culture could emerge and next an analysis into the existing construction project cultural frameworks is done. Finally, the conclusions have been drawn presenting the conceptual framework for construction project culture.

2. WHAT REALLY DESCRIBE CONSTRUCTION PROJECT CULTURE?

Culture is visible as a set of manifestations. Basically, the long list of cultural manifestations includes values, norms, basic assumptions, relationships, patterns of behaviours, rituals, heroes, symbols and formal practices such as; pay levels, structure of the hierarchy, job descriptions, and other written policies (Hofstede, 1980; Marrewijk, 2006; Martin, 2004; Zuo, 2008). Many researchers have tried to define culture by using these cultural manifestations. For example, Duarte and Snyder (1999 cited Zuo, 2008) defines culture as a set of learned mores, values, attitudes and meanings that are shared by the members of a group where culture is often one of the primary ways to differentiate one group from another.

With regard to a construction project culture, Marrewijk (2007) comes-up with the two episodes of culture of one Environ mega project in-relation to the cultural classification of cultural forms, practices and content themes introduced by Martine (2004). Here, Marrewijk (2007) indicates the presence of two dominant cultural episodes. The episode of the Gideon's gang (1996-2001) was dominant for innovative and entrepreneurial value orientations related to the content themes and during the episode of the Diplomats (2001-2004) these new value orientations replaced the former project culture during the realisation phase with control, financial, accountability, integrity, stability and lawfulness. However, mere presentation of these groups of cultural manifestations adds no value where the in-depth analysis of culture requires the understanding the relationship between these cultural manifestations.

Accordingly, 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 organisational culture. Schein (1984)'s elaborations focus on what artefacts and values reveal about basic assumptions i.e. values of an individual or a group lead to behaviour and when the behaviour begins to solve the problem which led the behaviour in first instance, that value is transformed into an underlying assumption (Hatch,1993). Further, as he describes, analysing these visible artefacts, it is possible to answer "how" a group construct its environment and "what" behaviour patterns are visible among the members. However, to answer the question "why" a group behaves in a certain manner, it is required to analyse the espoused values and basic assumptions (Schein, 1984).

As per Schein (1983) and Martin (2002), it is the underline assumptions that really helps to understand what the culture of a given group is and trying to interpret culture based on the artefacts, behavior patterns and behavioural norms which include the visible part of the culture is regarded as being misleading. Hofstede (1980) also refers these underlying assumptions as 'taken for granted values'. Schein (1983, 1984) explains basic assumptions as mostly unconscious and are taught to new members as a reality and as the correct way to view things. Values become apparent by interviewing key members of the organisation to identify the reasons for the behavior of the members. Nevertheless, to really understand the culture, it is important to identify the underlying assumptions.

Considering the importance of inner layers in culture, many researchers tried to interpret culture using values and underlying assumptions (refer Rokeach, 1979; Schwartz, 1994; Hills, 2002). Since underlying assumptions are the taken for granted values it is important to understand values in detail to really understand what underlying assumptions are. Values are micro-macro concepts. At the micro level of individual behaviour, values are motivating as internalised standards that reconcile a person's needs with the demands of social life. They allow individuals to evaluate the options that are available to them for action. At the macro level of cultural practices, values represent shared understandings that give meaning, order and integration to social living. (Parashar *et al*., 2004). Therefore, a value is an enduring belief in an individual or a group which gives preference to a course of action or thought to its opposite.

As stated by Hills (2002), Rokeach's (1979) thirty-six values are at most 36 values held by human beings and they are considered to be widely, and perhaps universally held. According to Yeganeh (2009), the most important characteristic of Schwarz's (1994) model of human values is that he studied both the content and structure of human values. The content of every value is related to the criteria people take into account when evaluating a situation or taking an action. By contrast, the structure is related to the organisation of these values based on their similarities and differences.

Value orientation theory by Kluckhohn and Strodtbeck (1961) is one of the most important theory of basic human values which has been very influential in the field of value research. Initially, they have put forward some three basic assumptions (Hills, 2002, p.4): "there is a limited number of common human problems for which all people must at all times find some solution"; "while there is variability in solutions of all the problems, it is neither limitless nor random but is definitely variable within a range of possible solutions" and "all alternatives of all solutions are present in all societies at all times but are differentially preferred". Further, Kluckhohn and Strodtbeck (1961 cited Maznevski *et al*., 2002, p.276) suggested six basic types of problems to be solved by every society together with possible three orientations for the same described as: 1) What is the nature of human beings: are they good, evil or neutral?; 2) What is our relationship to nature: are we subjugated to nature, in harmony with nature, or do we have mastery over it?; 3) What is our relationship to other human beings: is it lineal (ordered position within groups), collateral (primacy given to goals and welfare of groups), or individualistic (primacy given to the individual)?; 4) What is our primary mode of activity: is our basic orientation one of being-in-becoming, doing or reflecting?; 5) How do we view time: do we focus on the past, present, or future?; and 6) How do we think about space: is it public, private, or mixed?.

Having set out this value orientation theory, Kluckhohn and Strodtbeck (1961 cited Hills, 2002) then proposed a means of measuring the orientations it produced which are considered as a universal set of human values. They suggested intensive interviewing be used with a series of probing questions exploring each of the value dimensions with the interviewee. However, they also recognised that many people find it difficult to think in the abstract, so suggested that real-life situations be outlined which involved the particular value being investigated. Many of the researchers who made the attempt to capture values to interpret culture has followed the work of Kluckhohn and Strodtbeck (1961) (refer Schein, 1984; Hofstede, 1980). Considering the comprehensiveness, exclusiveness of dimensions, parsimony and possible application for individual and aggregate levels of the said theory (Maznevski *et al*., 2002), studying culture of construction project culture could be done following the value orientation theory. Schein (1984) identified a set of such underlying assumptions of organisational culture some of which are summarised in Table 1. Also, Hills (2002) has identified some different individual cultural underlying assumptions which are not included in Schein (1984)'s work. Fellow and Liu (2013, p.401) states that; "culture determines how we communicate, how we relate to other people, how we regard property, our interaction with the environment, and our perspectives of time The buildings we construct are potent symbols of culture". This statement better describe the importance of learning the underlying assumptions of the construction project team members because underlying assumptions could reason out all those actions mentioned by Fellow and Liu (2013). Hence, it is evident that understanding culture through values and underlying assumptions rather than elaborating merely through artefacts and behavioural features give lot of insight into the culture. However, as depicted by Fellow *et al*. (2007) another factor creating the complexity in culture of a construction project seems to be through the existence of different levels of culture on a construction project, which is discussed in detail next.

Table 1: Underlying Assumptions of Organisational Culture

Dimension	Questions to be Answered	Orientations
The organisation's relationship to its environment	Does the organisation perceive itself to be dominant, submissive, harmonising, searching out a niche?	Dominant, Submissive, Harmonising, Searching, out a niche
The nature of human Activity	Is the "correct" way for humans to behave to be dominant/pro-active, harmonising, or passive/fatalistic?	Dominant/pro-active, Harmonising, Passive/fatalistic
The nature of reality and truth	How do we define what is true and what is not true; and how is truth ultimately determined both in the physical and social world? By pragmatic test, reliance on wisdom, or social consensus?	Pragmatic test, Reliance on wisdom, Social consensus
The nature of time	What is our basic orientation in terms of past, present, and future, and what kinds of time units are most relevant for the conduct of daily affairs?	Past, Present, Future
The nature of human Nature	Are humans basically good, neutral, or evil, and is human nature perfectible or fixed?	Good,Neutral, Evil
The nature of human relationships	What is the "correct" way for people to relate to each other, to distribute power and affection? Is life competitive or cooperative?	Competitive, Cooperative
	Is the best way to organise society on the basis of individualism or groupism?	Individualism, Groupism
	Is the best authority system autocratic/paternalistic or collegial/participative?	Autocratic/paternalistic, Collegial/participative

Source: Adapted from Schein (1983)

3. HOW IS THE CONSTRUCTION PROJECT CULTURE ORGANISED?

The project culture seems to be affected by different cultures at different levels including national culture, industry culture, organisational culture and professional culture. Ofori and Toor (2009) identify the importance of understanding levels of culture and their relationship in defining the culture in a cross-cultural construction project setting. They explain that in a major construction project when members from different countries participate, it would be inappropriate to define a culture at national level because, although foreigners from different countries adopt the local culture, they still maintain some ties with their roots. In addition, when a construction project team is formed with different participants from different organisations, many difficulties seem to arise due to the conflicts of different business objectives and lack of sensitivity and tolerance of difference between participants. This highlights the importance of understanding organisational culture for successful project management (Fellow *et al*., 2007). Further, Rameezdeen and Gunarathna (2003) elaborate that consultancy organisations in Sri Lanka believe that their success depend on the development of human resources for achieving specific goals of the organisation which emphasises on a culture with loyalty, value traditions and openness. In contrast, contracting organisations are driven towards output maximisation where they encourage a competitive work environment and culture. Moreover, 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 people issues. Hence, it is apparent that organisational cultures have an impact on the project culture.

Kumaraswamy *et al*. (2002 cited Ankrah *et al*., 2009) have attempted to define construction project culture by looking at these impacts from different levels of culture. They identified 'organisational', 'professional', 'operational' and 'individualistic' sub-cultures as the principal elements that come together to evolve the culture within a construction project as depicted in Figure 1.

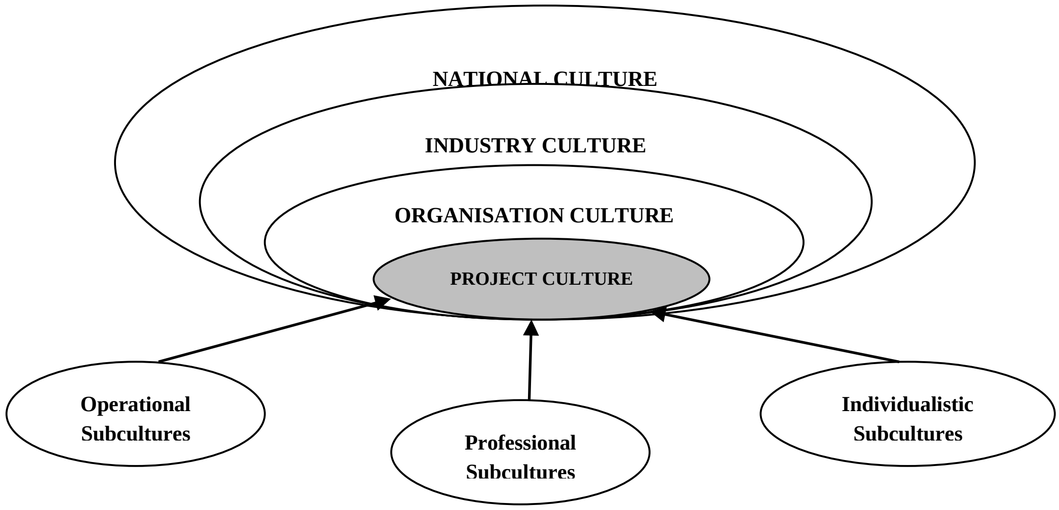

Figure 1: Sources of Typical Construction Project Culture
Source: Adapted from Zuo and Zillante (2005, p.357)

Here they argue that 'organisational sub-cultures' is mainly influenced by national culture and industry culture. At the same time, project culture could be affected by three other cultures: professional, operational and individual. 'Professional sub-cultures' are influenced by factors such as the type of members, origin and history and type of task/function. 'Operational sub-cultures' could comprise of quality culture, safety culture, and learning culture. 'Individualistic sub-cultures' are influenced by factors such as national culture, ethnic factors, social status and religion. As explained by Kumaraswamy *et al*. (2002 cited Zuo and Zillante, 2005), a number of components contribute to each sub-culture, where one or more sub-cultures may dominate, depending on their 'relative strengths'. Thereby, Hofstede's cultural model (1980, 1991) could be first used to assess the culture in each sub-culture and then to assess the whole project culture. Though the aforesaid framework seems insightful, it does not make the task of identifying and investigating the drivers of culture within the project easy.

Schein (1996) bring forward another interpretation of sub-cultures related to different occupations within an organisation. These occupational sub-culture are more similar to professional sub-culture depicted by Kumaraswamy *et al*. (2002 cited Ankrah *et al*., 2009). These sub-cultures of Schein (1996) included 'engineers' (technocrats) who design and monitor the technology supporting an organisation's operations; 'operators' who deliver products and services; and 'executives' who primarily focus on financial performance which was called engineering culture, operator culture and executive culture respectively. According to Schein (1996) organisational learning and change failures were primarily due to inadequate understanding of occupational cultures existing within organisations. It is because these occupational groups hold different views and interpret differently the same aspect due to the difference in their professional background differences which results in communication problems. Some shared assumptions stated by Schein (1996) include; related to engineers as; 'engineers prefer linear, simple cause-and-effect, quantitative thinking', 'engineers are safety oriented and overdesign for safety' related operators as; 'success of the enterprise depends on people's knowledge, skill, learning ability, and commitment', 'operators must be able to work as a collaborative team' and related to executives as; 'executives focus onfinancial survival and growth to ensure returns to shareholders and to society' and 'people are a necessary evil, not an intrinsic value'.

A similar classification could be brought into construction project team where the project manager, client's representatives, donors could be considered as executives who more in to financial performance and consultants as engineers and contractor and his personnel as operators. This argument is very much similar to considering 'professional culture' as the dominant sub-culture in construction project cultural model of Kumaraswamy *et al*. (2002 cited Ankrah *et al*., 2009). However, whether 'professional culture' the dominant sub-culture in construction project team is again an argument.

This existence of sub-culture groups in an organisations and project teams affects the shared view of culture put-forward by many researchers including Hofstede (1980) and Schein (1984). However, Martin (2004) disagrees with the definition of culture as a "shared" thing among the members of the organisation. As she depicts, all of these cultural manifestations are interpreted, evaluated, and enacted in varying ways because cultural members have differing interests, experiences, responsibilities and values. Further, more importantly, culture consists of the patterns of meanings that link these manifestations together, sometimes in harmony, sometimes in bitter conflicts between groups, and sometimes in webs of ambiguity, paradox, and contradiction. For these reasons, it is much too simple to define culture in unifying, harmonious terms, for example, in terms of values that are espoused by management and apparently shared by most employees. Therefore, it is worth looking into these three perspectives of culture explained by Martine (2004).

Martin (2002) conceptualise culture from three different perspectives; integration, differentiation, and fragmentation. The perspectives are complementary, in that each allows the researcher to investigate the blind spots inherent in the others (Kappos and Rivard, 2007). Integration refers to interpretations that lead to consensus across the whole collective. No ambiguity exists in members' interpretations of the manifestations and interpretations are clear to all. (Martin, 2002). Differentiation does not assume a collective-wide consensus on interpretations of the manifestations. This perspective concerns those interpretations of manifestations that lead to a consensus only at the sub-cultural level (Martin, 2002). Fragmentation assumes that vague interpretations of manifestations by members of the collective are unavoidable. The members of an organisation could interpret the manifestations in a number of different ways, thus never delineating islands of consensus, consistency, or clarity (Martin, 2002).

A case study of three retailing organisations done by Harris and Ogbonna (1998) found that that each of Martin's (2002) three perspectives corresponds to different hierarchical positions. The study of head office personnel found that they tend to adopt an integration perspective on organisational culture i.e., culture is viewed in terms of consensus and consistency. The store managers commonly adopted a differentiation perspective on organisational culture i.e. store managers view culture as dichotomous, inconsistent and characterised by subcultural consensus. Finally, shop floor workers tend to exhibit a fragmentation perspective on organisational culture where the views of shop floor workers tend to focus on the ambiguity, fluidity and complexity of organisational culture.

Hence, analysing construction project culture using the three perspective theory could bring in lot of insight in to the project culture. Similarly, a better understanding of how culture emerges would be another important area to be analysed in to in order to unveil the cultural stance. This would be discussed in next section.

4. HOW DOES CONSTRUCTION PROJECT CULTURE EMERGE?

Meudell and Gadd (1994), who argue on culture in general management, depict that 'history' is the key influence which affects culture where time allows for relationships to be built up, there is time for top management to exercise influence and for values to be created and transferred. Thereby, cultures are clearly visible with organisations due to their life span, but somewhat unlikely with a project. Further, this is an issue which seems valid for construction projects with fixed life spans.

Ankrah *et al*. (2009) identify that the client and contractor as dominant participants influencing project culture. Even, Zuo (2008) highlights the influence of client in creating the culture within the project team. Mainly the client's involvement is essential in relationship contracting to allocate resources throughout the project process. Further, it is highlighted that the capacity and the level of resources of the client (such as funds) directly impact the level of influence the client can exert on the project members. Moreover, Zuo (2008) depicts that this influence would not be visible in traditional procurement methods because in such procurement arrangements client will engage in the primary consultation only later the architect or the project manager will manage the project. However, Ankrah *et al*. (2009) do not indicate project manager as an influencing character for project culture in construction industry in United Kingdom. Nevertheless, Zuo (2008) identified that project manager has to take the responsibility in creating the culture within the project team. Further, Marrewijk (2007) elaborates in detail the two dominant cultural episodes in the Environ Mega project in Otherlands, due to change of the project manager. Therefore, it is a real time example for the implementation of strong project culture by a project manager. This supports the argument put forward by Schein (1983) that leader contributes to the creation of culture of a group by force or by his or her personality, however, According to his argument, this is not going to be a reality until group has overcome various crises of growth and survival, and has worked out solutions for coping with its external problems of adaptation and its internal problems of creating a workable set of relationship rules.

Going in line with the aforesaid argument, Schein (1984) depicts that patterns of basic assumptions of organisational culture are realised through the attempt of the group of people in coping with the problems of internal integration and external adaptation. Therefore, projects holding lot of similar characteristics to organisatons, it could be argued that the project culture is also emerged in the attempt to survive from the said internal integration (those that deal with the group's ability to function as a group) and external adaptation problems (those that deal with the group's basic survival). These problems of internal integration include handling issues of; 'strategy', 'goals', 'means of accomplishing goals', 'measuring performance' and 'corrections' while problems of internal integration include problems related to 'language', 'boundaries', 'power and status', 'intimacy', 'rewards and punishments' and 'ideology'.

If one wants to identify the elements of a given culture, one can go down the list of issues and ask how the group views itself in relation to each of them: what does it seem to be its core mission, its goals, the way to accomplish those goals, the measurement systems and procedures it uses, the way it remedies actions, its particular jargon and meaning system, the authority system, peer system, reward system, and ideology. When this is done, one will find that there is in most cultures a deeper level of assumptions which ties together the various solutions to the various problems, and this deeper level deals with more ultimate questions (Schein, 1983). Research work of Ankrah *et al*. (2009) on factors affecting project culture included lot of similar factors as to these said problems. For example; in problems of external adaptation and survival, 'goals' could include the factors such as number of variations, level of importance of the cost and health and safety while 'means of accomplishing goals' could include factors such as level of subcontracting. In problems of internal integration, 'boundaries' could be tallying the factor of participants involved and 'power and status' could be tallying the factor of level of influence.

Further, Zuo (2008) mentions that a strong culture could be created through effective communication between parties mainly through project meetings hold face-to-face. Even, Song (2008) depicts the importance of information and communication technology in creating a good team culture. In addition, Meudell and Gadd (1994), researching on the hospitality sector projects argue that a strong culture could be created in projects through proper recruitment and training. This is a further challenge considering that construction project teams are formed mainly based on technical capabilities and contractual relationships. Hence, next section discusses whether all the existing construction project culture models is able to answer all the questions being raised throughout this paper.

5. DO EXISTING CONSTRUCTION PROJECT CULTURE MODELS SERVE THE PURPOSE?

Zuo (2008) has carried out research studies on project culture in Australian and Chinese construction industries combining some popular organisational culture models (e.g. Cameron and Quinn, 1999; Hofstede, 1990 etc.) to suit construction project context. According to his proposed project culture model (refer Figure 2), project culture consists of five dimensions as; Integrative, Cooperative, Goal oriented, Flexible and People-oriented. In this model Zuo (2008) depicts the structure of the project culture or some practise dimensions he proposes and not the content. For example, according to Zuo (2008), project culture is 'flexible' and easy to change. The question arises is why practising a flexible atmosphere. It can be because the nature of human nature to be assumed as good so the flexibility is allowed which could provide a better clarification according to the value orientation theory of Kluckhon and Strodbeck (1961 cited Hills, 2002). Also, the project culture has the feature of being 'corporative' which raises the question 'why being corporative?'. One reason behind this could be because the project team has the assumption that best way the individuals within the projectteam should relate with others to be 'corporative'. It seems the cultural essence or which is called underline assumptions are not captured by the Zuo (2008)'s work. The better understanding would be to explain that the project team members assume that human nature is good and the best way to relating to other people is considering everybody as equal rather than saying it has the feature of corporation and flexibility. This is because, for example, if a change is to be introduced to the project culture and if it to be managed the most important is what are the underlying assumptions of people not mere its feature. When the change is introduced, the superiors are aware that going against the underlying assumptions would bring lot of resistance to the change.

Project Culture	**Integrative**	Inputs of various contributing parties (e.g. design, construction, consultant. etc) are encouraged in the early stage of project process.
	Cooperative	There are few conflicts during the course of projects. Emphasis is placed on aligning the objectives of different participants and organisations to a common goal - the objectives of the project. Teamwork is popular. The project participants collaborate with each other.
	Goal-oriented	More attention is given to getting the job done. The process of the project tends to be tolerated.
	Flexible	The way a project is processed is very flexible and easy to change. Innovative approaches, which include risk-taking, are encouraged and rewarded in the project process.
	People-oriented	It is high priority to develop team members' skills. No blame and celebrating achievements.

Figure 2: Proposed Project Culture Model
Source: Zuo (2008, p.274)

In addition, this project culture model has been developed for relationship contracting projects only. As described by Zuo (2008), relationship contracting or collaboration contracts are to achieve a common project objective which results in win-win situations for client and all other parties involved in the project including major features as all the parties sharing the risk and everyone being responsible for the success or failure of the project. Moreover, they explain that project culture tends to be different in different procurement methods. However, it is the traditional procurement method (where design and construction is carried out in two separate phases of the project) which is the most popular procurement method adopted in most of the construction industries (Love, 2002; Skitmore and Love, 1995). Therefore, whether the proposed project culture model is a fair representation of project culture is questionable.

Use of Competing Value Framework (CVF) developed by Cameron and Quinn (1999) to understand cultural orientation of thirteen Australian construction projects by Thomas *et al*. (2001) has been criticised by several other researchers. As argued by Zuo and Zillante (2005), general management derived organisational culture models such as CVF, have little consideration for the specific characteristics of construction projects. For example, the integration between the functional departments of one organisation, which is stressed in numerous organisational cultural models, should be modified to suit construction projects with the integration of the different functions (services) in construction projects.

Having identified specific research on construction project culture with their limitations, the next section discusses the conceptual framework developed for construction project culture for empirical study as the next of this study.

6. CONCEPTUAL FRAMEWORK FOR CONSTRUCTION PROJECT CULTURE

The answers to the three broad questions mentioned in Section 1 (i.e. 1) What cultural manifestations in deed represent construction project culture?, 2) How is the construction project culture organised? and 3) How does construction project culture emerge?) identified through a comprehensive literature review are mapped together using a conceptual framework for construction project culture. The conceptual framework is presented in Figure 3. From all the cultural manifestations discussed, it is the underlying assumptions that provide the real essence of culture (refer Section 2). Therefore, underlying assumptions of the construction project team members have been identified as the cultural manifestation for project culture in the conceptual framework. Thus, the triangle in the middle of the conceptual framework shows the boundary of construction project culture, which includes the three perspectives of underlying assumptions identified through literature review as the three main concepts, i.e. integrated underlying assumptions among all team members, differentiated underlying assumptions of sub-cultural groups and fragmented underlying assumptions among team members.

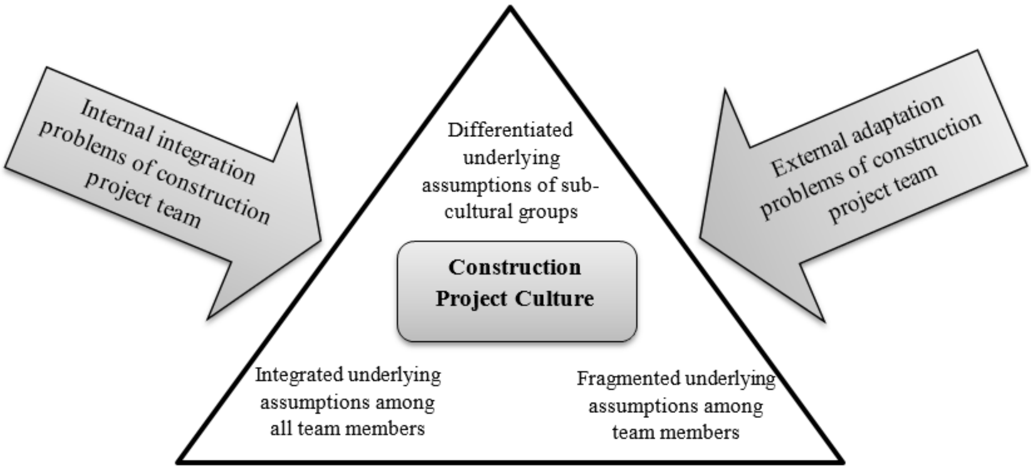

Figure 3: Conceptual Framework for Construction Project Culture

Shared view of culture has been identified as only one perspective of culture and presence of all three perspectives is expected in the context of construction project culture. The differentiated perspective represents the availability of sub-cultural groups within the construction project team. Sub-culture groups are to be identified as; 'executive', 'engineering' and 'operator' as described by Schein (1996) or as; 'organisational', 'professional', 'operational' and 'individualistic' as described by Kumaraswamy *et al.* (2002 cited Ankrah *et al*., 2009) depending on the decision whether professional sub-culture is the dominant sub-culture in a given construction project context.

The two arrows pointed toward the triangle indicate the internal adoption problems and external integration problems of the construction project team, which give rise to the underlying assumptions of the project culture. These problems could include many of the issues related to organisational cultural setting which give rise to organisational culture as identified by Schein (1983) (refer Section 4). This conceptual framework can be further strengthened with empirical data by applying it in a selected context. The next section draws conclusions for the discussion.

7. CONCLUSIONS AND THE WAY FORWARD

This literature review aimed at understanding project culture in construction project by bringing in literal arguments for three broad questions. Initial problem was to identify what cultural manifestations give the true interpretation of project culture for which the underlying assumptions were realised to support the most. The next problem was to understand how the construction project culture is organised. The literal arguments brought in were that project culture could be existing in sub-cultural groups and should be further analysed with integrated perspective, differentiated perspective and fragmented perspective to get an in-depth analysis since all these orientations could be existing within the project team. The final question raised was to understand how the project culture emerges. The internal integration problems and external adaptation problems depicted by Schein (1984) related to organisational culture are seem to be affecting the emergence of project culture as well. Hence, mapping all these ideas and arguments, a literal definition for project culture could be derived as follows:

"Construction project culture is the pattern of meanings that link the underlying assumptions of the project team members, some in harmony among all team members, some in conflict among sub-groups within the project and some in paradox for internal integration and external adoption of the project team."

A conceptual framework developed at the end of the literature review will be for better understanding of construction project culture (refer Figure 3). Further research proposed related this work could be developing methodological frameworks to gather empirical findings to test the validity of the stated definition and the conceptual framework for construction project culture.

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CRITICAL ANALYSIS OF ALTERNATIVE DISPUTE RESOLUTION METHODS USED IN SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

Construction disputes are of highly technical in nature and in fact intensive and multifaceted than other commercial disputes. The litigation method is the traditional way of dispute resolution and drawbacks of litigation have opened up the 'Alternative Dispute Resolution' (ADR) methods. The desirable features of ADR methods are fast, inexpensive, flexibility, confidentiality, minimum delay. This research attempts to address the issues and conflicting areas of ADR methods in the Sri Lankan construction industry. Attempts have been made to identify and analyse problematic areas which are highly influencing the ADR methods. The aim of this research is to evaluate ADR methods and suggest improvements to the ADR methods in the Sri Lankan construction industry.

This research is the result of surveys that were conducted to understand the experiences and usages of ADR methods. Two rounds of Delphi method surveys were conducted in order to identify problematic areas of ADR methods. Fifteen problematic areas and twelve potential improvements of ADR methods were identified during the Delphi survey round one. They were prioritised during Delphi method survey round two. Semi-structured interviews were used to get the extended view of the panel on top eight issues which were ranked in Delphi round two.

A pivotal conclusion of this research is that the stakeholders in the construction industry prefer "negotiation" method. Usages and awareness about negotiation were highly appreciated by the construction industry professionals. Professionals had a low level of satisfaction on the current practice of arbitration. Overall expectation of the construction industry by application of ADR methods is to provide best solutions within a minimal time and without damaging the reputation of involved parties. It was revealed that construction industry expects quick remedy than the less cost solution. It further revealed that the stair-step model of dispute resolution strategy is the best. The research further makes recommendations in order to make ADR methods more effective and efficient.

Keywords: *ADR Methods; Disputes; Potential Improvements; Problematic Areas.*

1. INTRODUCTION

In a Construction Project a number of professionals work together for the successful completion of the project. Different professionals have their own objectives which are to be satisfied through the project. This kind of involvement of professionals and stakeholders may create favourable grounds to create disputes (Walker, 1996). Conflicts would develop into disputes if they are not addressed well in initial stages (Brown and Marriott, 1999). Disputes may occur as a result of the actions or inactions of the Employer, the Contractor or the different consultants (Kheng, 2003). According to Astor and Chinkin (1992) litigation is considered as the standard and conventional dispute resolution method used in all over the world. However it is an expensive and time consuming method. Therefore, industry participants have moved toward Alternative Dispute Resolution (ADR) methods (Treacy, 1995).

Abeyaratne (2006) stated that Sri Lanka has been practicing ADR methods from the ancient era. In current context the methods and proceedings have to be changed to match modern business requirements as well as international usage. Negotiation, conciliation, mediation, adjudication, and arbitration are widely recognised and used ADR methods in Sri Lanka (De Zylva, 2006).

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Though the ADR methods have been evolved and practiced for considerable period of time, still there are gaps and limitations. Negotiation, being a non-binding ADR method is not always workable in bringing consensus at the end. This is because project may get differ from the anticipated manner and they may trigger the case to be handled with more formal methods such as mediation or conciliation (Essex, 1996). Mediation on the other hand only allow mediator to help and guide the parties to reach their own consensus solution. The parties can simply ignore the solution proposed by the mediator if they are not satisfied with it (Chau, 1992). Apart from that mediator has no power in imposing his solution on the matter (Harmon, 2006). Situation is almost same in the case of conciliation. These qualities of conciliation and mediation have made them difficult to distinguish from one another.

Institute for Construction Training and Development (ICTAD) has proposed *"ad-hoc"* Dispute Adjudication Board (DAB) as the method of dispute resolution in the Standard Bidding Document (SBD). In *ad-hoc* DAB, though the board is named at the initial stage they would not be called upon until a dispute has arisen. According to Bunni (2005), though it saves the time, benefits of the concept of dispute board are lost as parties do not invite adjudicator to visit the site and attend meetings. In addition, either full time or ad-hoc adjudication may lose their brightness as the decisions can be subject to a review or refer to arbitration or litigation (Chong and Zin, 2012).

As a whole, all the ADR methods are now facing problems (issues) *viz* not having time frame in resolving disputes and not having universal standards. Furthermore with the increased magnitude of the construction projects professionals no longer rely on a single ADR method, instead they prefer multi-tire ADR approaches.

2. LITERATURE SYNTHESIS

2.1. DISPUTES IN CONSTRUCTION INDUSTRY

Disputes in construction industry are inevitable, it is impossible for construction projects to be proceeded without a single dispute to be handled (Merrill, 2007). According to Morgan (2008), dispute can be recognised as any argumentative issues that the contracted parties disagree upon and that need to be settled within or outside the contract. According to Kheng (2003), subject matters of construction disputes are highly technical in nature and involve issues of law which are highly specialised and require as modes of proof documents. A construction industry dispute is thus one which is technically complex, tedious in the appreciation of the facts and the amount spend on the dispute can also be quite extensive. Construction disputes may cost significant measures in terms of money, personnel, time, and opportunity costs, if not resolved timely.

2.2. DISPUTES RESOLUTION REGIME

According to Kerzner (2006), in project management it is required to select a confronting, compromising, smoothing, forcing or avoiding conflict resolution methods in order to deal with potential conflicts. Dispute resolution takes further step by attempt to deal with unsettled conflict through binding approaches (Jannadia, Asaaaf, Bubshait, and Naji, 2000). Litigation and arbitration can be identified as binding approaches whiles negotiation, mediation and conciliation are considered as non-binding approaches. Not all disputes are resolved by court proceedings or in other formal or informal approaches based on ADR methods.

2.3. LITIGATION AS A TRADITIONAL DISPUTES RESOLUTION METHOD

As Ashworth and Hogg (2002) stated that litigation is a procedure used for dispute resolution with the intervention of state appointed judges Even though litigation comprises some significant demerits, it is still considered as the standard and conventional dispute resolution method used in all over the world (Astor and Chinkin, 1992).

In Sri Lankan context the courts of law and their jurisdictions are governed by the Constitution and Judicature Act No. 02 of 1978. For Commercial disputes subjected more than five million rupees, some jurisdictions are vested in Commercial High Courts which established by Provincial High Court Act No.

10 of 1996. All the other contractual matters in the construction industry are vested in District courts. The civil appellate jurisdiction are vested on Civil Appellate High Court, Court of Appeal and Supreme Court of Sri Lanka. Harmon (2003) states that litigation is a win-lose method of dispute resolution and there is a great potential that the dispute will not be resolved to the satisfaction of the parties involved.

2.4. MOVE TOWARDS ADR METHODS

Due to the fact that litigation requires enormous cost the United States construction industry began to seek alternative ways of dealing with construction disputes. According to Ashworth and Hogg (2002), Alternative Dispute Resolution methods are originated in the USA and was adopted in UK in the 1980s.

Alternative Dispute Resolution (ADR) methods are well-organised formal structured processes, which most of the time assisted by an external neutral third party. Construction professionals are becoming increasingly involved in mediation, arbitration expert determination and adjudication because of the fact that ADR methods provide increased scope for the involvement of non-lawyers. According to De Zylva (2006) negotiation, adjudication and arbitration are recognised and widely used ADR methods in the construction industry in Sri Lanka.

3. ADR METHODS AND THEIR PROCEEDINGS

3.1. NEGOTIATION

Negotiation is the most basic technique which is used for dispute resolution or problem solving. In the process of negotiation, the parties involved work out an agreement by direct communication. This is considered as a non-binding technique as the parties are not liable to execute the agreement. The process may be bilateral (between two parties) or it could be multilateral (many parties). Each party may utilise any form of external expertise it considers necessary and this is often described as “supported negotiating”.

3.2. MEDIATION

Mediation is a process, in which the parties are assisted with one or more third parties in their efforts to settle a dispute. These parties are neutral, impartial and not bias to any of the parties involved and shows the paths that the disputed can be settled (Ashworth and Hogg, 2002). The mediation takes place in a private, informal setting with a non-confrontational atmosphere. In Mediation a dispute is settled only if all of the parties agree to the settlement. Mediation focuses on interests, which means it is concerned more with the needs, desires and concerns of the parties than with their specific legal rights. However, the legal rights of the parties can serve as a reference point for the mediation process.

3.3. CONCILIATION

Conciliation is bit similar to mediation except for the fact that it involves a more separated examination of the situation and the official presentation of recommendations. However, in both mediation and conciliation the parties can either accept or reject the recommended solutions. The flexibility of proceeding with the recommendations, bind or not with the proposed terms of settlement, makes conciliation distinguish from adjudication.

3.4. ADJUDICATION

Adjudication may be defined as a process where a neutral third party gives a decision which is binding on the parties in dispute unless or until revised in arbitration or litigation (Gould, 2003). In adjudication when a dispute occurred a person who is having no connection with either side who are involved in dispute, decides the terms of settlement. This decision may be temporary binding. This is a mandatory pre-step before the final process may be commenced. In Sri Lanka adjudication procedure relating the construction matters is governed accordance with the ICTAD -Standard Bidding Documents (SBD) on conditions of contract. Adjudication is intended to be quicker and more cost effective than litigation or arbitration. It is normally used to ensure payment (although most types of disputes can be adjudicated). The adjudicator must generally decide the dispute in less than 42 days.

3.5. *ARBITRATION*

Arbitration is a process in which a neutral and independent third party or parties appointed by parties involved hear/s evidence and arguments from the parties involved in a dispute and settles the dispute by making a binding decision. The decision given is called an award. Arbitration is a more formal dispute resolution process than mediation. While mediators have no decision-making powers and assist parties in negotiating a mutually acceptable settlement of the issues in dispute, arbitrators are adjudicators who make decisions based on the legal rights of the parties. In this sense, arbitration is more like litigation, although it is less formal than litigation (Patterson and Seabolt, 2001). Arbitration grew up as a method to resolve disputes where those within the industry would agree privately to appoint a respected member of the industry to resolve their disputes.

4. SIGNIFICANT PROBLEMATIC AREAS IN THE ADR REGIME

4.1. *ISSUES IN MEDIATION AND CONCILIATION*

- Mediators and Conciliators have no powers of enforcement or of making binding recommendations.

Taylor and Carn (2007) stated that “Unfortunately, since mediation is non-binding, it may fail to produce a resolution and parties may have to look to binding resolutions such as arbitration and litigation”. According to Cheung (1999) that the parties are not satisfied with the solutions proposed by the mediator they can simply ignore them.

- Distinguishing between Conciliation and Mediation is somewhat difficult.

With regard to conciliation and mediation methods, one problem has been the difficulty in distinguishing between two. There lies a thin lining between conciliation and mediation in relation to the application of ADR methods. Conciliation proceeds with the appointment of the neutral third party by the parties to the dispute. This may enable the parties to identify the disputed issues and they may develop options and draw alternative solutions to reach the agreement. Therefore at present there seems to be a certain confusion as to the interpretation and one of ADR methods. According to ideas of National Alternative Dispute Resolution Advisory Council (1997), mediation and conciliation processes are having a number of common elements. A Sir Michael Latham also expresses dissatisfaction with the current conciliation and mediation methods available for resolving disputes in the UK construction industry.

4.2. *ISSUES IN ADJUDICATION*

Following facts can be identified as issues in adjudication;

- If the decision is not satisfactory, parties have to use litigation and arbitration methods. Accordingly adjudication becomes another waste of time.
- Decision depends on the adjudicator – There is no standard of procedure so the process and the decision could differ according to the adjudicator.
- Time period of the process is limited – Time may be too short for adjudicator to make the correct decision.

4.3. *ISSUES IN ARBITRATION PRACTICE*

Latham (1994 cited King 1998) has reported that arbitration which has been a favoured method of resolving such disputes, is under attack in the UK because of its’ perceived complexity, slowness, and expense along with the process. However, out of all above ADR methods, arbitration is the commonly practicing ADR method in Sri Lankan construction industry. Sri Lanka Arbitration Act No 11 of 1995 stated that arbitration principles and UNCITRAL Model Law. Researchers have shown some drawbacks in the Sri Lankan arbitration process like delaying the process, high professionals fees of the arbitrators, higher involvement of lawyers, less concentration on technical issues, unawareness of the procedure, different solutions given by different arbitrators, inability to conduct multi party disputes using arbitration and its limited jurisdictions, same procedure apply for all disputes and less satisfaction with a process. Accordingly, arbitration, along with its' disadvantages, is the most exercised ADR method in Sri Lanka and it has made the stakeholders of the Sri Lankan construction industry dissatisfied and their reluctance to proceed beyond bargaining and enter in to ADR regime. Jurists reveal that arbitration practice in Sri Lanka also declines because of its drawbacks and disadvantages over arbitration and as a result of its' rigid procedure it makes difficult to handle multiparty disputes.

Enforcement of New York Convention is another problem relating to arbitration. Some countries in the Middle East have entered into construction contracts with Sri Lankan contractors are not parties to the New York convention and all have to follow with other regional arrangements such as the ***Amman convention*** which requests all arbitral proceedings to be conducted in the Arabic language.

According to jurists following can be identified as other issues in arbitration;

- Although usually thought to be speedier when there are multiple arbitrators in the panel, juggling their schedules for hearing dates in long cases can lead to delays.
- Arbitrators are generally unable to order interlocutory measures against a party, making it easier for a party to take steps to avoid enforcement and award.
- It is also a problem that Multi-party arbitration is not practised here in Sri Lanka.

4.4. ISSUES IN GENERAL IN ADR REGIME

According to Brown, Cervenak and Fairman (1997) ADR methods are considered to be having advantages over traditional modes of dispute resolution, they may not effective in serving some goals related to rule of law initiatives. Even they are counterproductive in following aspects,

- Define, refine, establish and promote a legal framework.
- Redress pervasive injustice, discrimination or civil rights problems.
- Resolve disputes between parties who possess greatly different levels of power or authority.
- Resolve cases that require public sanction.
- Resolve disputes involving disputants or interested parties who refuse to participate or in the ADR processes.

Not having universally or internationally accepted proceedings for some areas in ADR methods and it can be identified as a major issue;

- No universal standards for the Convention on services process
- No universal standards for the Convention on taking evidence.

ADR methods are expected to be saving time than litigation however there is no pre-set time framework for settling disputes in ADR practice. That can be identified as a major drawback of some of the ADR methods.

Following aspects can be identified as some of the other issues regarding ADR practice;

- At present there seems to be certain confusion as to interpretation and use of ARD methods.
- Procedural differences between Common Law and Civil Law systems.
  Eg. Foreign sovereign Immunity Clauses

5. RESEARCH METHODOLOGY

As the research tends to identify the current practice of ADR methods and potentials of improving the ADR methods in Sri Lankan construction industry, qualitative and quantitative mix-approach was selected. Two Delphi rounds including to questionnaire rounds and semi-structured interviews were conducted for collection of data. The questionnaires were distributed among professionals of various contracting and consulting organisations and dispute resolution practitioners in Sri Lanka. The data gathered in round one were intended to identify the potential issues, problematic and conflicting areas in ADR regime and potential solutions to ADR methods. In the second round of the questionnaire, the intention was to prioritise the issues and solutions based on the scale of identification by the respondents. In the semi-structured interviews the most significant issues and solutions were further analysed with the help of industry experts.

Statistical data analysis had to be used in this research study to analyse the collected data. In Delphi round one the identification of issues and solutions were done by considering the percentage identifications. Data analysis for the Delhi round two was done using Mean Weighted Average and Relative Importance Index. The interviews were analysed using Content Analysis method. N Vivo – 7 was used as a supporting tool in performing content analysis.

5.1. *DESIGN OF SURVEY QUESTIONNAIRE*

Delphi round 1 is designed for identification of different ADR methods used in the Sri Lankan construction industry, their problematic areas of ADR methods, critical attributes pertaining to the ADR methods and potential improvements to the ADR regime in Sri Lanka. In the first round of the questionnaire survey, a list of eight ADR methods, eleven important critical attributes of ADR methods, thirteen advantages, ten disadvantages, seventeen issues/problematic areas of ADR methods and fourteen potential solutions to the ADR methods were provided as identified from literature review and with the use of preliminary interviews. The experts and the other professionals of industry were specially asked to identify the problematic areas/issues of ADR methods and potential solutions to ADR methods that has been prevailed in the construction industry.

In the round two questionnaire the respondents were asked to indicate the levels of critical attributes, advantages, disadvantages, issues and solutions on ADR methods. The level of status on ADR methods, critical attributes, advantages, disadvantages and issues on ADR methods are categorised to a scale of 1-5 denoting 1=Very Low, 2=Low, 3=Medium, 4=High, 5=Very High. It is used Lickert scale for Delphi round 2.

6. RESEARCH FINDINGS AND DATA ANALYSIS

6.1. *FINDINGS OF THE RESEARCH*

Table 1 shows the percentage of awareness on the given ADR methods in the Sri Lankan construction industry.

Table 1: Percentage Awareness on ADR Methods

ADR Method	Percentage Awareness
Negotiation	100.00%
Adjudication	96.88%
Arbitration	90.63%
Mediation	62.50%
Conciliation	34.38
Expert determination	15.63%
Med-Arb	3.12%
Mini trial	3.12%

The issues and problematic areas in ADR methods which were identified through literature survey were presented to the respondents. Almost all the proposed solutions received more than 35% identification as potential solutions of improving ADR regime in Sri Lankan construction industry. Therefore they all were selected to be presented in second round.

Table 2 summarises the response received and results identifications of the issues are given in front of them. The table presents MWR and RII values and the ranking of the issues according to the value that they received. If MWR value is more than 2.50 then it is considered that industry identifies given point as an issue that have to be addressed. The identified potential solutions, which are ranked 1 to 10, were selected in forming the structure and questions of the semi-structured Interview Guideline.

Table 2: Rank of the Issues

	Potential Issues	RII	MWR	Rank
1	At present, Arbitration is a complex and adversarial process.	93.33	4.67	1
2	No time framework for the settlement of disputes through ADR methods.	77.50	3.88	2
3	Dispute avoidance (partnering) is not used by parties to the contracts.	75.83	3.79	3
4	Mediators and Conciliators have no powers of enforcement of making a binding recommendations	75.00	3.75	4
5	Mediation method has unique characteristics, however, mediation is rarely practiced and not that much popular with compared to the other ADR methods.	72.50	3.63	5
6	Low level of satisfaction of ADR methods, proceedings and their outcomes	70.83	3.54	6
7	Low popularity of ADR methods	64.17	3.21	7
8	Awareness of ADR methods and their related legislation/ standard conditions of contract is low.	64.17	3.21	7
9	Distinguishing between Conciliation and Mediation methods are difficult.	59.17	2.96	8
10	Involvement of experts for ADR methods are low.	59.17	2.96	8
11	Mini-trials are most appropriate for factual disputes. However, mini-trials are not popular.	56.67	2.83	9
12	ADR methods have become expensive	51.67	2.58	10
13	Involvement of legal professionals and retired judges in ADR regime.	48.33	2.42	11
14	Multi - party arbitration is not practice in the construction industry.	45.00	2.25	12
15	ADR methods are not universal applications in resolving any kind of construction disputes	36.67	1.83	13
16	Not having a universally or internationally accepted proceedings for following aspects of ADR;	34.17	1.71	14
17	Enforcement of New York convention - Sri Lankan contractors work with Middle-East countries, where regional arrangements (eg. Amman Convention) are practiced instead of New York convention.	15.83	0.79	15

The potential solutions which were identified in Delphi round 01 are also ranked using RII method. Here also likert scale of 5 levels was used. The purpose of this ranking is to prioritise the actions that have to be taken in order to make ADR regime more effective and efficient.

The table 3 presents MWR and RII values and the ranking of the potential solutions according to the RII value that they received. If MWR value is more than 2.50, then it is considered that industry identifies given point as a potential solution.

Table 3: Potential Solutions Ranked according to the RII Values

	Potential Solutions to Overcome the Existing Issues	RII	MWR	Rank
1.	Introduce dispute avoidance (eg. partnering) strategies for parties to the construction contracts.	83.33	4.17	**1**
2	Introduce dispute management mechanism to construction projects.	79.17	3.96	**2**
3.	Conducting awareness programmes on ADR methods	74.17	3.71	**3**
4.	Speed up the proceedings of ADR methods.	74.17	3.71	**3**
5.	Change the attitude of construction professionals concerning ADR regime.	73.33	3.67	**4**
6	Introduce time framework to the ADR methods for settlement of disputes.	72.37	3.67	**5**
7.	Increase technically qualified construction professionals as arbitrators, adjudicators and mediators for settlement of construction disputes.	70.50	3.63	**6**
8	Legalise the adjudication method through a legislation and give a statutory status to it.	65.00	3.25	**7**
9.	Introduce mini-trials for resolving factual disputes.	56.67	2.83	**8**
10	Establishment of an institute for practicing, developing and regulating ADR methods	56.67	2.83	**8**
11	Introduce recommended plain dispute resolution Clause /Agreement without any ambiguities for construction disputes	51.67	2.58	**9**
12	Appointment of a Lawyer, Architect and an Engineer to the ADR tribunal/ panel may be very appropriate.	50.83	2.54	**10**
13	Introduce rules and guidelines for ADR methods used in the construction industry in Sri Lanka	50.00	2.50	**11**
14	Introduce laws/rules for non-involvement of legal professionals in ADR practice.	43.33	2.17	**12**

The identified potential solutions, which ranked 1 - 14, were selected in forming the structure and questions of the Semi-structured Interview Guideline.

7. FINDINGS IN SEMI-STRUCTURED INTERVIEWS

Professionals prefer ADR methods over litigation due to their inbuilt advantages which can't be catered in formal litigation proceedings. Negotiation can be considered as the most preferred ADR method. Basically the following aspects have contributed to negotiation for being so;

- Process is not adversarial, it may preserve the business relationship among parties
- Process is economical as there is less involvement in third party and different settings for hearing the case
- Things such as time schedule, venue can be decided by the parties
- Stakeholders think that being the parties involved to the dispute resolution they themselves are the best people to find out a win-win solution

Arbitration can be considered as a well-established ADR method which is governed by Arbitration Act, No.11 of 1995. However it seems that the industry professionals are not satisfied with the arbitral proceedings due to following reasons:

- Long time (delay) and high cost incurred through the process
- Process is being adversarial
- Business relationship between parties are damaged

Industry professionals are having moderate view on adjudication, they highlighted that it would be better if the local standard conditions of contract included the provisions for fulltime Dispute Adjudication Board. In addition they said it will be better if the adjudication given legal assent through a legislation.

Mediation is having number of advantages over other formal ADR methods such as Adjudication and Arbitration. But following issues have make mediation to be not popular in the construction industry;

- Becoming a mediator is very difficult as it require lot of capabilities such as interpersonal skills, communicational skills and vast experience on top of all ability to deal with mental and psychological aspects of parties involved.
- There is no incentive in standard forms to refer dispute to mediation.
- There is no legal assent in construction mediation.

8. CONCLUSIONS

It seems that the ADR regime in Sri Lanka is confined to methods such as Negotiation, Mediation, Adjudication and Arbitration. However, ADR methods in the construction industry of Sri Lanka are not properly developed. The resolution and management of disputes or conflicts in the Sri Lankan construction industry may have three typed of approaches. Those approaches are,

- Preventive
- Amicable
- Judgmental resolution system

Amicable settlement through negotiation is more expedient and much cheaper. As a matter of fact it is true that there are inherent characteristics in arbitration. At present arbitration is costly and require longer duration for the award. Most of the time Arbitration Act has not failed and it has worked fairly well, but the problem is with the environment which it practices. Therefore using simple modification, more benefits can be obtained. Mediation and adjudication methods are suitable for settlement of disputes in the construction industry. It is difficult to establish Mediation as it is, at once. It is better to implement mediatory effect as an incremental change rather than mediation itself. Then gradually step by step mediation may get popular. In addition it will be a good idea to have a little direction in local standard conditions of contract, towards the mediation in dispute resolution clauses. ICTAD and FIDIC standard documents give efficient steps throughout the way from amicable solutions and finally arbitration.

It has become an issue that there is no governing body to regulate ADR methods in Sri Lanka. ADR practice can be considered as a secondary profession which plays a supportive role in the construction industry. There are some institutes which have taken initiative to bring ADR practice in to a professional level. . But it would be better if the institute is formed and established through a legislation which is devoted to construction related ADR methods.

Further this research presents evidence supporting the view of the stair-step model of ADR methods which was identified in the literature review. It has confirmed the practitioners' acceptance of the stair-step model of dispute resolution and it was understood that negotiation was best suitable method and arbitration as the least suitable ADR method. However, even though negotiation achieves the highest index values in the survey results identified the unavailability of enforceability and binding of the outcome in negotiation as well as in mediation.

9. RECOMMENDATIONS

In the light of the interviews and the results of the questionnaire survey which were analysed and the followings are recommended to enhance the standard of ADR regime in the Sri Lankan construction industry.

- Require immediate review of existing standard conditions of contracts practiced in the construction industry. With out implementing international standard conditions alone, it is required to assess the suitability of those conditions to the Sri Lankan construction industry.

- Implement proper mediation centres for small and medium level construction stakeholders.
- Maintain qualified panel of adjudicators and arbitrators by a regulating body of the construction industry.
- Adjudication requires statutory recognition. Hence, there is a requirement of new statute which control and recognise adjudication as an ADR method in Sri Lanka.
- Most of the time ADR proceedings are conducted on an *Ad hoc* basis. Separate individual professional organisations provide their professional services in dispute resolution. Therefore it is necessary to implement new institution to conduct construction related ADR methods.
- Most of the construction professionals who are involved in dispute resolution criticise the lawyers' involvement for the settlement of disputes. It is required to select suitable professionals for ADR methods who have both legal and construction related competence. Construction industry professionals need to handle more applications of laws than construction problems usually call for solution by a combined and balanced use of technical knowledge, management skills and legal principles.
- There are many publications related to construction law and ADR methods in developed countries. However in the Sri Lankan context there are limited publications related to the ADR regime. Therefore, relevant institutes should conduct research oriented conferences in ADR methods and encourage professionals and their institutes to publish research articles and other publications related to ADR methods.
- Educational institutes have to experiment and take initiative to introduce ADR methods and make the industry aware of the advantages of such methods. Then there will be an incentive to industry people to adopt them into their practice. In addition they can organise CPD events which may allow experts to share their knowledge with others.
- Introduce speedy arbitration in order to minimise the time spent on the process.
- Establishment of Dispute Review Board (DRB) from concerned professional institutions and government organisations.
- In the construction industry in Sri Lanka, there does not appear to be much concern given as to how the fundamentals of engineering, architecture and law must be used in the process of managing disputes. It is vital to adopt those principals.
- Introduce prevention methods which are essential for the avoidance of disputes in the construction industry.
- Sri Lankan construction industry shall give attention to avoid or reduce the incidence of disputes. There are few recommendations to avoid disputes as;
    1. Ensure that client, consultant and contractor have adequate and correct appreciation of their respective professional and ethical obligations.
    2. To be propose compressive and clear contract agreements.
    3. To be ready all parties for amicable resolutions.

Public and privately owned infrastructure development projects are increasing throughout the country. ADR methods need to be developed in the processing of areas of construction law, project management and contract administration. Partnering is a process which aims to create a good preventive approach. It can lay the foundation for better and more productive working relationships on the project, by establishing of trust and frankness in communications the parties get to know about common goals and foster a problem solving attitude. At the end of the day ADR methods have to cater the expectation of the industry by providing impartial and decisive solutions in minimum time span and cost without damaging reputation of the parties.

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CULTURAL CONTINUITY AS A VITAL FACTOR IN DELIVERING IDENTITY, MEMORY AND SENSE OF PLACE: A CRITICAL STUDY OF URBAN TRANSFORMATION WITH SPECIAL REFERENCE TO PETTAH IN COLOMBO

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ABSTRACT

Most Asian cities are characterised by rapid urban metamorphosis and mostly the urban changes are based on planning mechanisms through spatial and land use methodologies and supported by globalization. In Colonial-contemporary cities, it is often seen that recent planning and development approaches undermine the cultural representation and memory of the place in their transformation process.

The study is scoped within the discussion of morphology, in relation to urban transformation and planning, in the context of urban settings (places) in Pettah, Colombo. It aims to re-examine cultural continuity in relation to the memory of a place in transforming urban settings. Methodologically, urban-cultural morphological study couples with spatial anthropology for field investigation and data transcoded into urban design planning schemata. Referring the literature on this subject area, certain parameters to measure the appropriate cultural transformation have been identified and the analysis of this situation is supported by the observations and personal communications.

The research has identified the socio physical and socio cultural relationships of transforming urban settings which are meant to be regeneration of built masses but, mostly the renovations for irreplaceable urban settings where people celebrate the sense of place.

Keywords: *Cultural Continuity; Sense of Place; Spatial Anthropology; Sustainable New World Encyclopaedia; Urban Transformation.*

1. INTRODUCTION

Today cities are undergoing socio-physical and economic changes as never happened before in most Asian countries and developing countries thus Sri Lanka is also not an exception. To deliver a better sort of movement for people and functions, to build up community relationships and also to make a place of remembrance, cities are specially planned. There should be a balanced built environment to maintain a certain pattern in a city and also to elaborate a slight entertainment of the city. Currently with the changes, the historic urban façades of the city are in danger of fast fading.

“Every citizen has had long associations with some part of his city, and his image is soaked in memories and meanings” (Lynch, 1960, p.1).

With historic built mass certain communities have their own relationship and way of life; a culture, which is now being disturbed. Transformation of these urban settings with historic references happens, sometimes with total negligence on some historic buildings and sometimes with total contrasting application. Due to that, the way of living of a particular community will be disturbed or their life time values will be disappeared, which allows cultural crashes.

Based on the above concerns, this study is focused on the relationship of people and their urban settings, which are transforming with the current development trends in Sri Lankan urban context where there should be a high concentration on cultural aspects to ensure particular cultural continuity to an urban setting.

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Rapid development and urbanisation disturb the cultures bonded to the built environment and also a considerable level of cultural transformation is not visible in the current development trends in local context. These situations made the research interest to find out the contribution of urban settings in emerging the city character while ensuring memory, identity and sense of place with the identification of the relationship between such urban setting and socio economic and socio cultural development. Further this research validates appropriate sustainable urban transformation assessment criteria and figures out the enhancement given by the cultural continuity on the identity and memory of a particular urban setting.

The study is scoped within the discussion of morphology, in relation to urban transformation and planning, in the context of Pettah in Colombo and aims to re-examine cultural continuity in relation to the memory of a place in transforming urban settings. The study was carried out not considering Pettah as a whole, but in five pre-identified places within the area to harness more qualitative data and information.

2. URBAN SETTINGS AND ITS TRANSFORMATIONS

2.1. URBAN SETTINGS

Amos Rapoport (cited in Jagadisan and Fookes, 2010) also argues for the need to conceptualise 'environment' in general, and to consider types of environments. So that the environment or the settlement can be understood as; a) The organisation of space, time, meaning, and communication; b) A system of settings; c) The cultural landscape; d) A consisting of fixed, semi-fixed, and non-fixed elements.

At the very first, a space is required to form a settlement or an environment. With the time the space got developed serving its stake holders. Eventually a comprehensive settlement can be seen that delivers a meaningful understanding about the area. That expressive quality is the communication of an environment. To keep an appropriate communication with both inside and outside an environment needs a system of settings. Therefore it is clear that a system of settings physically characterises an urban setting. The social appreciation, feelings, activities and requirements equip such urban settings towards their life or the sustainability. That socio-cultural participation culturally characterises an urban setting. Physically available objects in an urban setting become components of it which support in the structuring process of urban settings.

2.1.1. COMPONENTS OF URBAN SETTINGS

With reference to Halprin's (1972) works, an urban setting is understood as a physical space generated through static or stable, temporary and movable components in a socio-economic and socio-cultural process. Therefore the research discusses urban settings through following components.

- **Permanent Structures -** Permanent components that boundary an urban setting, are built with more stable materials such as concrete, steel and brick with distinct characters or styles. The function and co-related activities combined to these built fabric are fixed, and they cannot be changed overnight. They are branded as two dimensional plots in figure-ground maps which show the relationship of an urban setting to its surrounding.
- **Temporary Structures -** These structures are not fixed in the setting and built out of light-weight materials. They are required to meet some functional necessities mostly for a certain period of time such as during special religious festivals, seasonal celebrations, etc.
- **Mobile Structures -** According to Rahul Mehrotra (2008) kinetic activities focus on to the gaps of the major activities accommodated in permanent and temporary structures. Most of these informal activities run on mobile structures that ease the movement of goods in place to place. In a broader perspective these mobile structures are the driving force of 'life' of an urban setting.
- **Open Spaces -** Aforesaid components of an urban setting become the basic factors to outline the voids or the open spaces in the setting. These spaces are the non-built plots of land. Either they are defined not to be built in order to keep green spaces or they are still not taken into consideration to put up buildings. The open space provides a relief to the eye in reading different building styles in an urban setting.

2.1.2. CHARACTERISTICS OF URBAN SETTINGS

Halprin (1972, p.11) explains urban settings as "…where the crowds gather and people participate in the exciting urban interrelationship which they seek as social human beings". The particular building might be individual but its setting is very important for the reason that these buildings are values of a certain social strata. At the same time some of them are places of remembrance where they have historic backgrounds and related styles. Visiting places like parks, plazas, squares, shopping and transportation areas have to be socially organised. Jacobs (1995), Landry, Greene, Matarasso, and Bianchini (1996) discuss about the physical qualities, That are considered in this research.

- **Accessibility -** Entry points to particular study area
- **Bringing people together -** The attraction of the study area
- **Publicness -** Reasons to be hanging around and the area get crowded
- **Livability -** Social integration into particular study area
- **Safety -** Crime state of the study area
- **Comfort -** Physical and psychological ease and convenience
- **Participation** - The level of movement and activities of people
- **Responsibility** - Supply of required satisfaction throughout the area
- **Archaeological history** - The value of historic reference
- **Architectural heritage -** Importance of different built styles
- **Landscape, topography, amenities, and landmarks**
- **Attractiveness and legibility of public space**
- **Entertainment**
- **Sub-cultures**
- **Traditions of public social life, civic traditions, festival and rituals**

2.2. TRANSFORMATION OF URBAN SETTINGS

Transformation is a process performing throughout a considerable period of time. In urban studies, urban changes or the structural modifications and alterations of cities are considered as urban transformations. These amendments in the city structure caused due to the development trends worldwide. Development is a concern of all the countries to move onwards in terms of social, economic, cultural, technological approaches and etc.

- **Physical Transformation -** During the process of urban transformation physical change of the urban setting or the place becomes an important factor. That particular change elaborates the level of transformation. In its simplest idea physical transformation is the change or the advancement of the built environment that can be seen over time. Alternative systems of construction methods and alterations for the elements of the built setting can be noticed during such transformation.

- **Cultural Transformation** - The urban setting needs life in it. This liveliness is not an easy approach because it is a kind of psychological assessment of a selected place. Generally the social involvement in an urban setting shows the life. This global phenomenon is strengthened by the following statement. "Livability is not only a matter of urban form, it is also a matter of personal preference" (Neuman, 2005, p.16). Neuman shows the connection between social preference and urban setting. So it is understood that if the physical setting is transforming towards new degrees of built form, the social preference is also to be transformed to fit the new urban formation.

3. PLACE AND CULTURAL CONTINUITY

3.1. PLACE

A place is a thoughtful entity characterised by cultural and human aspects of physical space. "This character consists both of concrete things having material substance, shape, texture, and colour and of more intangible cultural associations, a certain patina given by human use over time" (Trancik, 1986, p. 113). Trancik

(1986) further explains that even though a place is unique there may be physically same boundaries. Therefore the term place derives its uniqueness through its cultural content. It is the appreciation of such physical space by a group or groups of people. Relph (1976, p. 3) declares that “A place is not just the ‘where’ of something; it is the location plus everything that occupies that location seen as an integrated and meaningful phenomenon”.

3.1.1. IDENTITY OF A PLACE

An identity is a sort of recognition. The physical components of an object render its identity. Generally the term ‘identity of’ speaks out the bounded system of aforesaid physical components where the term ‘identity with’ always relates to other similar objects. “We recognise the identities of people, plants, places and even nations” (Relph, 1976, p.45). When the identity of a place is taken into consideration there are physical components but people look at it differently. There are different cultural groups who search certain qualities. They may see many of the components but they define a place with their experience, feeling and attitude.

3.1.2. MEMORY OF A PLACE

Once a person has experienced a place some characteristics of that place is autonomously recorded in his mind. That can be either a special physical component that exist in the particular location or a significant activity or a function that is special in the particular location. Moreover, some people see some places in their day to day activities. For an example a person who travels to his work place may see some places every day. At this instance unconsciously his eyes may follow particular built environments and they are recorded in his mind. The important factor is when he is about to recall a place some characteristics may come into his mind very quickly. That is the identity of place he has absorbed during his experience. Each and every experience makes a memory with the time pass. This memory of a place is a significant factor in finding out one’s own location (Lynch, 1960; Relph, 1976).

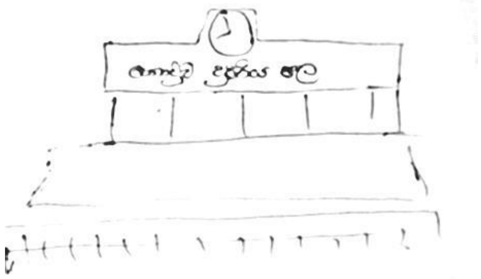


Figure 1: Imagery of Pettah - A Sudden Recall of Built Environment, Sketch by a Participant in the Research

3.1.3. SENSE OF A PLACE

How people experience places becomes an important area to be pondered. As Relph (1976, p.8) reveals “Yet, however we feel or know or explain space, there is nearly always some associated sense or concept of place”. The human dimension is also matters in the experience of a place. Tuan (as cited in Relph, 1976) treats this idea with the statement “…that provide the fundamental dimensions of left and right, above and below, in front of and behind, within reach and beyond reach, within hearing and beyond hearing, within sight and beyond sight” (p.9). Knowledge and attitudes are different from one person to another. Therefore they become subjective. So the individual experiences should be accompanied with an elementary understanding of the context of the place as a group of all relevant cultures to appraise the ‘sense’ of a place.

Kevin Lynch (1960) says that the visual sensation of colour, shape, motion, or polarisation of light, as well as other senses such as smell, sound, touch, kinesthesia, sense of gravity and perhaps of electric or magnetic fields are different kinds of indications to structure and identify the environment. He further articulates that the recognition of a place or an object must have a meaning for the observer whether practical or expressive.

According to Gordon Cullen (1995, p.11) colours, textures and scales are very significant characteristics of places that people experience. Then they get the impressions of the architectural styles of the built environment. Finally they relate themselves into it; emerge a personality.

3.2. CULTURAL CONTINUITY

Culture is a very broad area which has no single definition. Generally culture is described as a combination of cultivated human behaviours over time. Burnett Tylor, a 19th century anthropologist represented the cultural evolutionism states "Culture, or civilisation, taken in its broad, ethnographic sense, is that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society" (Tylor, 1929).

Landry *et al*. (1996) come up with a building related definition for culture. In fact a culture is a kind of way of life which is also an art of living. To support the living systems a reference is needed. Therefore one's experience of a place and time becomes a memory and these several memories or experiences get together where the people are getting together. So the continuation of this similar kind of experience is building specified because Landry *et al.* mention that culture is about a lived experience of a place; the reference of physical context. A place is defined with the presence of built environment. The psychological relationship to the place can give an idea of its own future, because an identical activity pattern or a way of life is attached to that particular place.

The culture is a vague term at all because it can be either related to smaller social groups with all most same activity patterns and living styles or at the same time to a whole nation consists of a huge number of such social groups that depict a distinct character or many among other regions. So the main component of the culture is the human being because his behavioural patterns or any other human related aspects are taken into consideration under the term 'culture'. For this research culture is a collective of several sub-cultures and a sub-culture defines as an identical group of people with similar ways of living. Social involvement in the place is an essential factor in urban design, because the places are for people. Kevin Lynch (1984, p.48) advocates, "*We must see any place as a social, biological, and physical whole, if we mean to understand it completely*".

4. CASE STUDY ANALYSIS

4.1. THEORETICAL POSITION

Throughout the formation of a city there are major concrete developments to shelter different types of activities and functions. So the people who involved in such activities are very familiar to this built environment and there is their own identity of "place". With the urbanisation there are more job opportunities and therefore people tend to come into these developing areas. In earlier built environments in urban areas there were well-planned master thought to facilitate the city and people. So that the people who built up relationships with the city those days, are the social-roots in generating cultures based on built environments. But in the present situation, most of the urban built forms are covering by the new additions to them and also by the new buildings coming up. Further it is worst in terms of large hoardings and light weight trucks as mobile structures appear closer to the roads that disable one's sight towards built environment. So now the issue is those massive structures are getting hidden in the city and therefore the value of them is being neglected or missed by the present generation. The glory of the building gets damaged along with this negligence and ill-treatment.

But on the other hand it is acceptable that there can be an urban transformation towards urban sustainability in the long run. Though it causes the disappearance of some parts of built environments, the identity and the memory retain with some celebrative characteristics. Preserving an iconic building is not that much easy because it has to be thought of its surrounding and response from the society. Anyhow, socio-economic forces cannot be restricted. Urban settings are commercially active in general. Therefore, selling – buying activities become dynamic features. So the tactful approach in selling methodologies followed by almost all the sellers is being closer to the society. Temporary structures and mobile structures enable such approach in urban settings. Therefore identity of place, memory of place and sense of place through the built environment degrade eventually.

A place that faces these issues needs a regeneration to pick up the continuity of the culture. The patterns of the urban space have high impacts on the community and the culture. Therefore, both physical and psychological rhythms and patterns are very considerable factors of a place to the people to keep a reminder of a “space” and sense it.

4.2. SELECTION OF CASE STUDY

The study is focused on urban settings, which are being transformed and already transformed. General appreciation of a place in terms of identity, memory and sense of place is the major concern of this research. But it is a perceptible factor that the current development is biased only on physical aspect of transformation. Pettah in Colombo; the busiest commercial area of the country, which has historic backgrounds was selected as a case to support this research.

4.2.1. PETTAH

Before Colombo becoming the commercial capital of the country, Pettah area was characterised as an administrative zone. Eventually Pettah got developed with compressed trade and other commercial activity concerns.

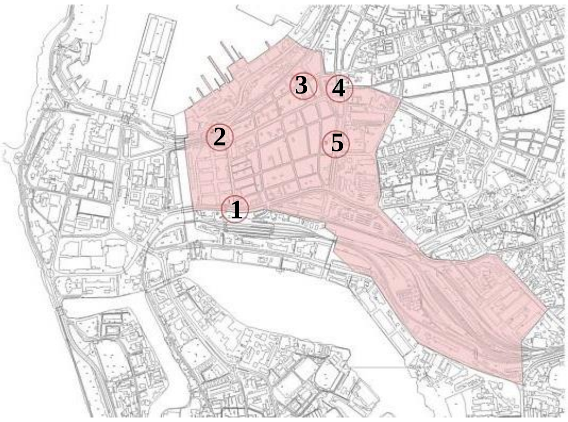


Figure 2: Pettah and its Surroundings
Source: Survey Department of Sri Lanka

Pettah is highlighted in this map of Colombo and the circled areas are the selected places for the study.

1) Malwaththa Road entrance from Olcott Mawatha
2) Khan Clock Tower
3) St. John’s Fish Market converting into a Gold Market
4) Gaswork Junction with Bell Tower
5) Bodhiraja Mawatha

During the preliminary studies on this research there were 10 interviews conducted by the author as pilot surveys to identify the major aspects of public considerations.

When the culture is considered, it is divided into two main streams. They are Locals and Strangers. The big picture which is available is a combination of these two particular communities and their activities responding to the built environment. This is where the issue comes in because, today whole Pettah is considered as a shopping area. Therefore many people attracted to Pettah. The only identity that people have today is Pettah is full of shops, which is very true but, at the same time there are lots of interesting and historically valued places in the same setting. With the development, the owners of these buildings have modified their property to meet a maximum commercial arrangement rather than appreciating such important buildings.

4.3. FRAMEWORK FOR THE ANALYSIS

During the study on components of selected places, 10 pilot surveys were carried out to figure out the special key aspects of particular places. Both Physical and Cultural characteristics are supported by the observations and photographic surveys. Police records data were collected from the Pettah Police Station. Both formal and informal interviews (30) strengthen the socio-cultural position behind the selected places. The questionnaire and the imagery survey sessions were conducted on 2 days for 400 people. After the pilot surveys, the questionnaire and the imagery survey were carried out among 200 people per day at selected 5 places (40 people each). There were 2 complete rounds from place 1 to place 5 interviewing 20 people at each place to cover 200 people. After the interviewing sessions on day 1, thorough observation, photographic and personal communication sessions were carried out for continuous 12 days and again the interviewing sessions for the remaining 200 people were carried on the 14th day following the day 1 process.

4.4. ANALYSIS

1) **The links of identity, memory and sense of place with the components of urban settings, physical characteristics and cultural characteristics.**

   a) Identity of a place emerges with the components of that place. Permanent structures become the most important built component because most of the times a static building or couple of buildings cast an identity to the particular setting. Sometimes temporary structures also create an identity of a certain place.
   b) Memory and sense of place directly link with the physical characteristics of that place but the components also have a considerable weightage - Spatial Anthropology analysis.
   c) Identity, memory and sense of place become more strong and meaningful with the cultural characteristics - Social Anthropology analysis.

This analysis contains a lot of data in tables with particular photographic surveys of each selected place (place 1 to 5) and based on those analysed data and information, the research proceeded to the analysis part 2; figure out the sustainability of each place. At this point the research links with Kevin Lynch's (1984) good city form theory to evaluate the sustainability of the particular places and the research has found that the 5 performance dimensions of good city form theory can be related with the twenty data variables which were used in the analysis part 1 as components of urban settings, physical characteristics of urban settings and cultural characteristics of urban settings. Therefore the following data analysis supports the research to consider the sustainability of the study areas.

2) **Assessment on Kevin Lynch's Performance dimensions - evaluation chart**

Table 1: Place Sustainability Evaluation Criteria for Pettah, Colombo

Performance dimension	Data Variable	Comments for the Places				
		Place 1	Place 2	Place 3	Place 4	Place 5
VITALITY	Safety	Enabled	Enabled	Partial	Enabled	Enabled
	Comfort	Satisfied	Satisfied	No	Barely	No
	Subcultures	Dynamic	Freezed	Regular	Dynamic	Dynamic
	Traditions	Dynamic	Unique	Absent	Dynamic	Dynamic
SENSE	Permanent structures	Average 3 floors	Average 2 floors	Average 3 floors	Average 4 floors	Single story
	Temporary structures	Many	Few	Many	Many	Many
	Mobile structures	Many	Few	Few	Many	Absent
	Open spaces	Few and busy	Few	Many	Few and Busy	No
	Legibility	Satisfied	Satisfied	Barely	No	Satisfied
	Entertainment	Absent	Absent	Absent	Absent	Absent

Performance dimension	Data Variable	Comments for the Places				
		Place 1	Place 2	Place 3	Place 4	Place 5
FIT	Publicness	Available	Available	Available	Available	Available
	Liveability	Satisfied	Barely	Barely	Satisfied	Satisfied
	Fitness	Pleased	Dis-Pleased	Dis-Pleased	Pleased	Barely pleased
ACCESS	Accessibility	High	High	High	High	High
	Bringing people together	High	Low	High	High	High
	Archaeological history	Not available	available	Not available	available	Not available
	Architectural heritage	Disapp-aring	Remai-ning	Conver-ting	Remai-ning	No
	Landscape Landmarks	Highly available	Highly available	available	available	Highly available
CONTROL	Participation	High	Low	High	High	High
	Responsibility	Satisfied	Barely	No	Satisfied	Satisfied

Comments for the each place on the respective data variables are given 'colour grading' as follows.

(green)	-	Good	100%
(yellow)	-	Average	50%
(grey)	-	Poor	Nil

With the above table the research analyses the sustainability through several charts and graphs. Above grading is offered to come to a numerical state for the qualities of the listed factors and each performance dimension is given one or more data variables. Therefore to clarify the content of a performance dimension, aforesaid colour grading is used. Therefore to clarify the quality of vitality of a place there are 4 data variables to be concerned. According to the colour grading system, vitality is clarified by the total sum of percentage for 4 data variables divided by 4 (the average percentage is used). Likewise all the 5 performance dimensions for each place are clarified and analysed data elaborated with a main graph and several charts and graphs. Finally the research evaluates the sustainability of Pettah with the average percentages of performance dimensions calculated for 5 particular places.

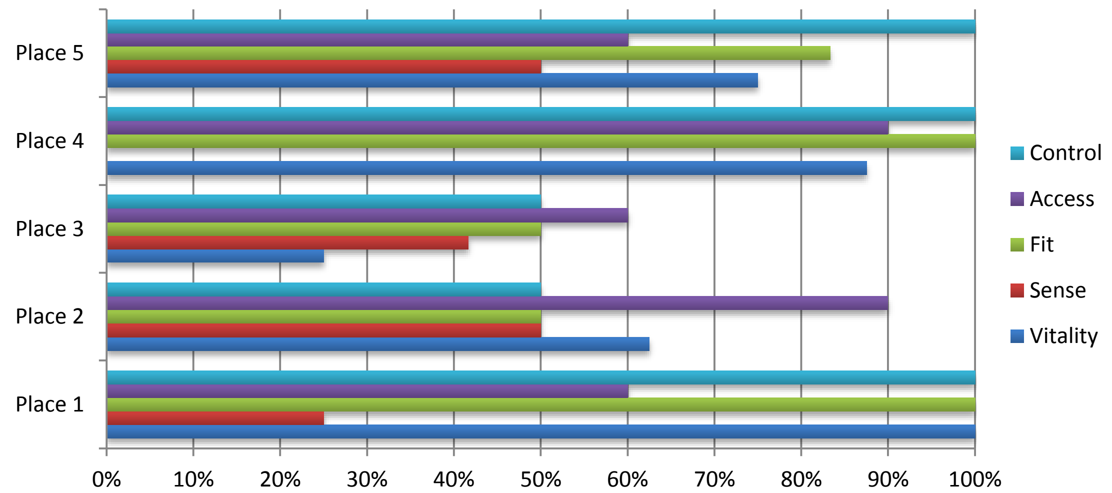


Figure 3: Place Sustainability Evaluation among Selected 5 Places

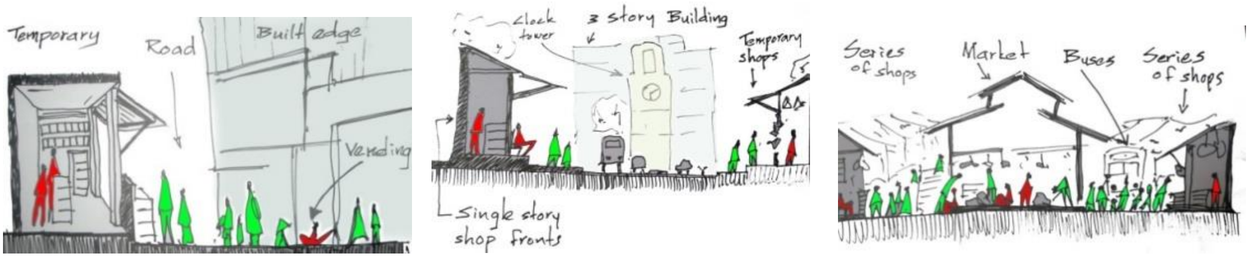
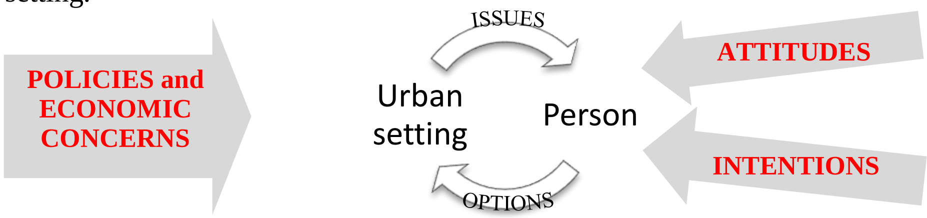


Figure 4: Some of the Cross Sections to Elaborate the Characteristics of Functioning in Pettah, Colombo

4.5 FINDINGS

a) During the development process a change in the urban setting leads to the changes in its social behaviour.

b) Social participation always figures out options to face issues come out from the particular urban setting.



c) Considered urban setting is always personalising.

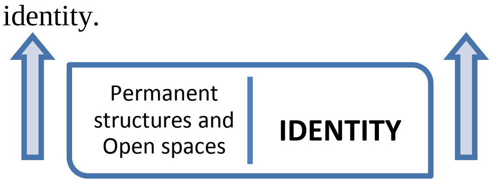
5. CONCLUSIONS

Responding to the capitalist urbanisation a rapid development is visible in Pettah area based on economic concerns. Generally each and every floor inch becomes valuable for the merchants for their profits. Therefore they all are expanding their selling area to catch the maximum consumer rates. Currently Pettah is over densed and responding to the overflowing business activities and space needs, the government is proposing vertical development. Being familiar to the countries in all over the world, it is a clear fact that a physical development can be achieved through buildings in city planning. But the corresponding cultural or the social transformation and the provision of the cultural existence become a vital consideration due to the fact that urban settings or the places are for people. Therefore the stakeholding sub cultures and other users and relevent people should be considered as key to achieve sustainable urbanisation.

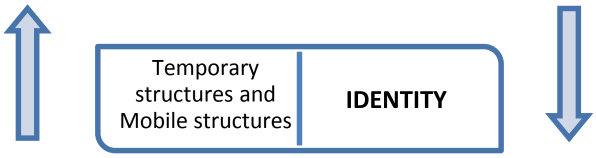
Therefore an identity of a place should be provided enabling people to make memories over that. To welcome more people to achieve publicness and the livability, the particular place should have been planned in a sensible way. The live wire of any given place is the paticipation of people. It is a global phenomenon.

The research revealed the following potentials during the study.

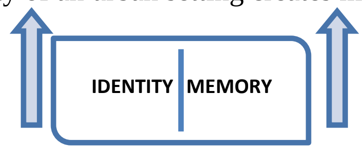
1. The increase in the number of Permanent structures and the Open sapaces of an urban setting has a potential increase in its identity.



2. The increase in the number of Temporary structures and the Mobile structures of an urban setting has a potential decrease in its identity.

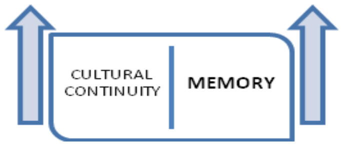


3. The high potential of idenity of an urban setting creates more opportunities to keep memories.



4. The quality increasement of spatial anthropology increases the sensibility of the particualr urban setting.

Pettah is currently loosing its identity mainly due to increase of temporary structures and overflowing of temporary commercial and selling activities without any place reference. The permanent structures are being covered by the temporary structures and mobile structures. Therefore the building façade is not visible at most cases and street front is not well defined causing problems of the orientation and identity of the place. This makes a situation that one can not experience the place with physical bearings to the place. Further all the open spaces and also some of the pavements of very crowded areas are being filled with mobile structures, temporary expansions of shop fronts and moving vendors. But still people's identity Pettah is as a large shopping area with a lot of crowd. It is an identity that arises because of the social participation. Therefore, the existence of the sub cultures and their activities have increased the level of identity.



The existence of sub cultures was re-interpreted as the cultural continuity in the body text. So cultural continuity delivers the identity of a place. In the same momentum people have soaked an idea of publicness relevent to the area. It becomes an memory of the place depicted by the participation or the existense of people. In further details the research found that some of the areas are ethnically significant. For an example the Main Street is full of shops and near the Jami-ul Alfar Mosque situated in a lane from the Main Street, where the Muslim population is comparatively high. So the people have a memory of the majority Muslims there. Further these Muslims are constructing an attachment to the original mosque which was built in 1909 facing the Main Street. This situation portrays that the cultural continuity delivers a memory of the place which is identifiable.

Both the above two outcomes reinforced by the existence of sub cultures and their activities. Therefore Pettah must have a sensible environment. But the research found that the built environment of Pettah is not very comfortable and the projected sustainability chart for Pettah has a low percentage for its sensibility.

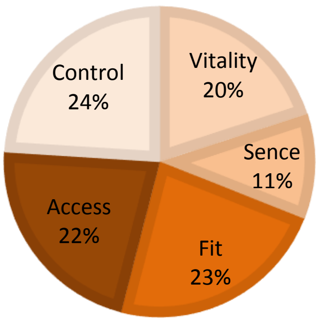


Figure 5: Projected Sustainability of Pettah along with its Urbanisation

Here the vitality, fitness and control are social concerns that Pettah is responsible for its stakeholders. There are lots of accessibilities to places in this area as a whole. Even though the physical built environment creates very less sensibility for Pettah, the publicness has become an outstanding factor that has been addressed by the business activities of the area. This presence of human activities generates the sensibility of the area. People who come to the area feel dynamic human activities. Therefore the cultural continuity delivers a sense of place for people to relate themselves with others and their activities. Generally on Sunday evenings and other special holidays more than two third of the shops are closed and Pettah has very low crowds, because the built environment has no potential of attracting people. Only the existence of sub cultures and related activities catch the social participation.

Therefore the cultural continuity of Pettah becomes a vital factor in delivering its identity, memory and sensibility because the personalisation of the area stands over the physical transformation and ensures cultural existence with alterations and options in human activities and behaviour. But to respond the issues regarding the urbanisation of the area these sub-cultures also transform slightly in the long run.

Based on the findings of this research about Pettah, further researches can be carried out specially on the social behaviours responding to the urban changes in city development, personalisation of urban settings over time and the importance of informal characteristics caused by the urban transformation towards sustainability.

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DESIGNING A WHOLE-LIFE COST INDEX FOR NON-RESIDENTIAL BUILDINGS

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ABSTRACT

The study investigates the whole-life costs of non-residential Green Mark certified building developments in Singapore to derive useful information for teaching, research and practice. When industry stakeholders like building owners, architects, engineers, quantity surveyors, builders and facility managers have detailed information about the initial and operating costs of different types of buildings, they would be able to apply whole-life costing to their existing or new projects with the intention of achieving value for money, as well as environmental sustainability. Data is collected from Green Mark certified building projects starting from 2005. Statistical analysis is performed on the collected data to generate the information required to build the cost database. The Paasche Price Index method is used to produce a weighted composite index for Singapore's non-residential building sector by applying 2005 as the base year.

Keywords: *BCA Green Mark Scheme; Price Index; Sustainability; Whole-life Costs.*

1. INTRODUCTION

The Singapore Economic Review Committee, set up in December 2001, had envisioned to remake Singapore through "new challenges and fresh goals", with the aim of transforming her into a dynamic global city (MTI, 2003). Among the goals set for the construction industry to upgrade capability, a new possibility was identified for its domestic enterprises to develop niches in eco-efficient design, environmental technologies, and green products and services. These areas come under Singapore's Green Plan 2012, which is a blueprint for achieving environmental sustainability. In view of the strategic plans, the signal was clear that in order for Singapore to achieve and maintain its position as a global city, the construction industry must among its other goals be able to produce and offer quality and environmentally-friendly buildings as a show of sustainable development.

Responding to the calls for the construction industry to build up expertise in environmental and ecological technology, the Building and Construction Authority (BCA) had developed the Green Mark Scheme as a strategic programme to encourage property developers, building owners, designers and contractors in Singapore to adopt "green building" practices. The Scheme was launched in January 2005 and it would apply to new and completed buildings. In 2006, the Green Building Master Plan was launched to encourage more building owners and developers to own and develop more environmentally-friendly buildings. Since 2005, the number of Green Mark building projects in Singapore has increased exponentially from only 17 in the first year to 1,000 in February 2012. At present, about 13% of the buildings in Singapore have achieved the BCA Green Mark standard. Clearly from this, we have arrived at a stage where there is sufficient project data of green-rated building developments to enable studies of whole-life costs to be carried out on a national basis.

The consideration of whole-life costs in the design and operation of building developments is a key part of sustainable development. It is also a vital component in achieving value for money for the building owner. Whole-life costs can be considered at various stages of the procurement process - at the initial stage of identifying a need and developing a business case, when producing specifications and when awarding a contract to achieve value for money (OGC, 2003). Whole-life costs are commonly divided into three broad categories: initial capital costs, operating costs and disposal costs (refer Figure 1). In essence, whole-life costing will take into account running costs such as energy usage, maintenance requirements, disposal costs

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such as recycling, as well as the initial purchase price. The life span of the product will also need to be considered.

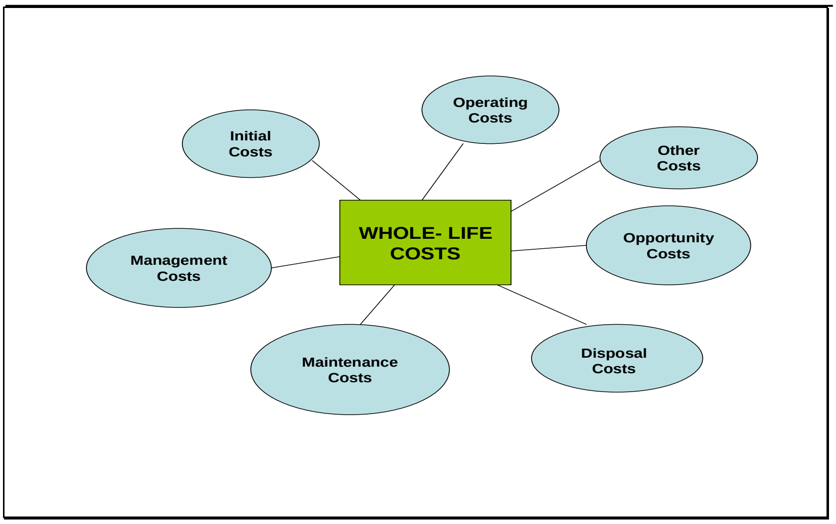

Figure 1: Components of Whole-life Costs of an Asset
Adapted from Addis and Talbot (2001)

2. DEFINITION

Life cycle costing is defined by Kirk and Dell'Isola (1995) as "an economic assessment of an item, area, system, or facility that considers all the significant costs of ownership over its economic life, expressed in terms of equivalent dollars. Life cycle costing is a technique that satisfies the requirements of owners for adequate analyses of total costs."

3. AIM AND OBJECTIVES

The main aim of the study is to design a whole-life cost index for non-residential buildings in Singapore. However, in the course of constructing the index, it involves investigating and analysing the whole-life costs of non-residential Green Mark certified building developments to derive information useful for teaching, research and practice. For instance, when industry stakeholders like building owners, architects, engineers, quantity surveyors, builders and facility managers have detailed information about different types of buildings' initial and operating costs, they would be more willing to apply the concept of whole-life costing to their existing or new projects with the intention of achieving value for money, as well as environmental sustainability.

The four objectives are outlined as follows:

a) To collect data of group building elemental costs that adopts the Singapore Standard Code of Practice CP80: 1999 classification to generate average cost percentages for commercial, industrial and institutional building types. The elemental groups are: (i) Site Preparation, (ii) Substructure, (iii) Superstructure, (iv) Finishes, (v) Fittings, Fixtures and Furnishings, and (vi) External Works.
b) To generate ratios of 'Cost of Building Services' to 'Total Cost of Building' for commercial, industrial and institutional building types. It is to investigate whether a relationship exists between this ratio and the function of the buildings analysed.
c) To construct a Non-residential Whole-life Cost Index on an annual basis. The index series begins in year 2005.
d) To create a Whole-life Cost Database that contains data of non-residential buildings' initial capital costs and operating costs (eg. annual energy and water costs, maintenance and repair costs, replacement costs, residual costs and other costs). The building types include commercial, industrial and institutional developments.

4. Significance of Concept

Construction industries in the advanced countries, such as the UK, USA and Australia, have been over the years advocating whole-life costing practices and have developed detailed standards and guidelines to assist industry stakeholders to apply the technique to manage the total costs of building projects. For instance, the internationally well-established Building Cost Information Service (BCIS) owned by the Royal Institution of Chartered Surveyors in the UK has developed and maintained a database of costs pertaining to building operations and maintenance since the 1990s. The National Institute of Building Sciences (NIBS) in the US has produced a standard for life-cycle cost analysis as part of its Whole Building Design Guide to educate industry stakeholders on how to use the technique in order to manage whole-life costs of building assets. In Australia, the New South Wales Treasury has developed a guideline for Life Cycle Costing as part of advocating total asset management in the light of growing pressures to achieve better outcomes from building assets. However, in Singapore, while there is a national Building Tender Price Index Series to guide industry stakeholders on tender prices of public and private-sector building projects, it still lacks a body of knowledge (in terms of a centralised database) concerning whole-life costs, specifically the costs of operating/running a building. Having a Whole-Life Cost Index essentially helps to enhance our knowledge of managing total costs of a typical building which must encompass operating and maintenance costs because it is during the asset's service life that more resources are consumed.

5. Approach

Data is mainly collected from Green Mark certified building projects starting from 2005. Non-Green Mark buildings are also used if good/complete data is available. Only non-residential building projects are considered - commercial, industrial and institutional types - because the data of operating costs of these types can be more easily obtained from a centralised source. On the other hand, for residential developments, collecting such data might not be too feasible as it would involve obtaining it from many different households. The Singapore Standard Code of Practice for Classification of Construction Cost Information or SS CP80: 1999 (Singapore Productivity and Standards Board, 1999) is used to classify the group building elements, while the American NIBS' Classification of Life Cycle Cost Components (NIBS, 2010) is adopted to classify the cost components. Statistical analysis is performed on the collected data to generate the information required to build the cost database.

The approach of the study can be presented in two parts. The first part is to study the average cost percentages of the group building elements and to generate ratios of 'Cost of Building Services' to 'Total Cost of Building' for commercial, industrial and institutional building types (refer Figure 2). The second part looks at constructing the Whole-Life Cost Index using the *Paasche* Price Index Method which produces a weighted composite index (refer Figure 3). The weights to be applied are calculated from the average proportions of value of contracts awarded for the three non-residential project types between 1996 and 2005. The buildings must have at least been running for 6 years to contain sufficient data on operating costs. The index series begins in 2005 (i.e. the base year).

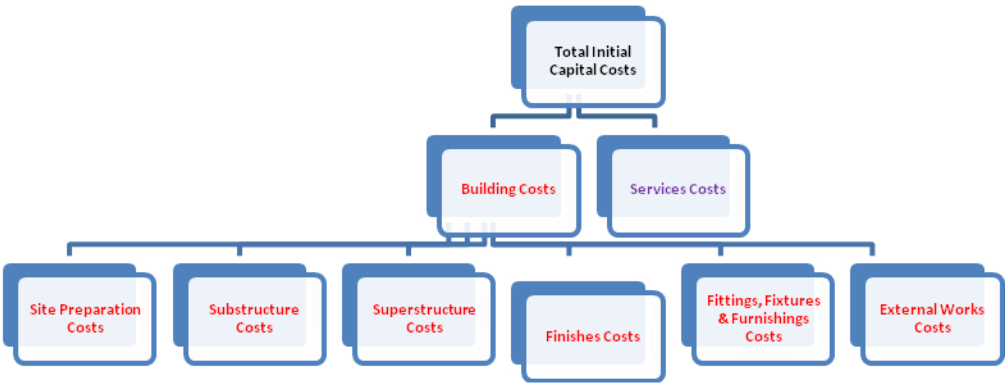

Figure 2: Components of Total Initial Capital Costs of an Asset
Adapted from Singapore Productivity and Standards Board (1999)

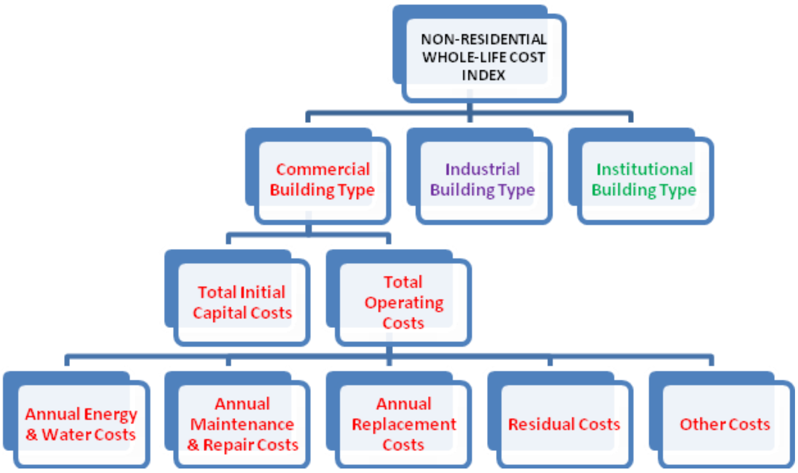

Figure 3: Components of the Proposed Non-residential Whole-life Cost Index
Adapted from NIBS (2010)

6. METHODOLOGY

The proposed Whole-Life Cost Index is a weighted composite index and is constructed using the *Paasche* Price Index Method. The formulation of the *Paasche* Price Index is expressed as:

$$\frac{\sum P_i \times Q_i}{\sum P_0 \times Q_i} \times 100\% \qquad \text{(Eq: 01)}$$

where, Pi = current year price; P_0 = base year price; and Qi = current year quantity.

In the first stage of constructing the proposed Index, the weights of the two main components of whole-life costs have to be established for each of the three types of non-residential buildings (Commercial, Industrial and Institutional types). The two components are:

- Total initial capital costs; and
- Total operating costs.

A sample of Green Mark certified buildings between 2005 and 2009 is used for this purpose to obtain their average proportions.

Establishing the weights for each building type:

Whole-Life Cost (C) = Total initial capital costs (C1) + Total operating costs (C2) (Eq: 02)

The ratios of C1: C and C2: C are calculated for each sample project. The average ratios are calculated from the sum of ratios for all sample projects divided by the number of sample projects.

The derived weights for each building type are applied in this manner:

Whole-Life Cost Index (WCI1) (Commercial Buildings)
$$= \left[\frac{(\text{Average ratio C1:C}) \times \sum Pi \times Qi}{\sum P_0 \times Qi}\right] + \left[\frac{(\text{Average ratio C2:C}) \times \sum Pi \times Qi}{\sum P_0 \times Qi}\right] \qquad \text{(Eq: 03)}$$

Whole-Life Cost Index (WCI2) (Industrial Buildings)
$$= \left[\frac{(\text{Average ratio C1:C}) \times \sum Pi \times Qi}{\sum P_0 \times Qi}\right] + \left[\frac{(\text{Average ratio C2:C}) \times \sum Pi \times Qi}{\sum P_0 \times Qi}\right] \qquad \text{(Eq: 04)}$$

Whole-Life Cost Index (WCI3) (Institutional Buildings)
$$= \left[\frac{(\text{Average ratio C1:C}) \times \sum Pi \times Qi}{\sum P_0 \times Qi}\right] + \left[\frac{(\text{Average ratio C2:C}) \times \sum Pi \times Qi}{\sum P_0 \times Qi}\right] \qquad \text{(Eq: 05)}$$

where, Pi = current year price; P_0 = base year price; and Qi = current year quantity.

In the second stage, the weights of the three types of non-residential buildings have to be established. The three types of buildings are:

- Commercial buildings;
- Industrial buildings; and
- Institutional buildings.

The value of contracts awarded for the three types of buildings between 1996 and 2005 is used for this purpose to obtain their average proportions.

Establishing the weights for the three non-residential building types:

Total Value of Non-Residential Buildings (N) = Total Value of Commercial Buildings (N1) +
Total Value of Industrial Buildings (N2) +
Total Value of Institutional Buildings (N3) (Eq: 06)

The ratios of N1:N, N2:N and N3:N are calculated and the derived weights is applied in this manner:
Whole-Life Cost Index = [(Ratio N1:N) x WCI1] + [(Ratio N2:N) x WCI2] + [(Ratio N3:N) x WCI3]
(for All Non-Residential Buildings) (Eq: 07)

7. DELIVERABLES

The main deliverables are as follows:

- Average cost percentages of group building elements for commercial, industrial and institutional building types.
- Ratios of 'Cost of Building Services' to 'Total Cost of Building' for commercial, industrial and institutional building types.
- A Whole-life Cost Index Series for non-residential building developments that begins in year 2005.
- A Whole-life Cost Database that contains data on initial capital costs and operating costs for commercial, industrial and institutional building types.

8. PRELIMINARY FINDINGS

The 36-month research which started in November 2012 is at the stage of data collection. A template that is formatted to contain all the standard building elements has been prepared for this purpose. A simplified version of the template is shown in Table 1.

Table 1: Template for Cost Data

No.	Main Group	Sub Group		Capital Cost ($)	Percent (%)
1.	Development and Construction Costs	a.	Substructure		
		b.	Superstructure		
		c.	Internal finishes		
		d.	Fittings and furnishings		
		e.	Services		
		f.	External works		
			Total:		100%
No.	**Main Group**	**Sub Group**		**Annual Cost ($)**	**Percent (%)**
2.	Operation and Maintenance Costs (Annual)	a.	Occupancy (eg. electricity, water, cleaning, security, etc.)		
		b.	Maintenance and repair		
		c.	Replacement		
			Total:		100%

Building projects that have been awarded a Green Mark rating are obtained from the website of BCA and letters sent to the owners, as well as their project consultants, to solicit help with the data collection. The number of non-residential buildings identified by their year of completion is shown in Table 2.

Table 2: Number of Green Mark Rated Buildings by Year of Completion

Type of Building	2005	2006	2007	2008	2009	Total
Commercial	8	5	11	12	25	61
Industrial	1	1	1	2	9	14
Institutional	2	2	2	7	4	17

The construction of the index applying the *Paasche* Price Index Method involves the re-pricing of each project's bill of quantities (BQ). This document provides the complete information on prices and quantities at current levels (i.e. *Pi* and *Qi*). The method of cost significant items re-pricing is adopted for this purpose as it recognises that a relatively small number of items in any BQ represents a high proportion of the cost significant items. Research has shown that generally about 80 percent of total costs are contained in less than 20 percent of the total number of items in a BQ. Therefore, the index is constructed based on re-pricing those cost significant items in order to save time in the re-pricing process. Across 13 work categories, a group of 68 cost significant items with their respective unit rates is obtained from the relevant publications of Singapore's construction costs (Davis and Seah, 2008; Davis, and Seah, 2010) (refer Table 3). The 2007 and 2008 unit rates published in the cost handbooks have been adjusted using BCA's National Building Tender Price Index (BTPI) to produce the 2005 base year rates.

Table 3: Number of Cost Significant Items for Main Construction Work Categories

No.	Main Work Categories	No. of Cost Significant Items	Unit Rate of Cost Significant Items
1.	Excavation	6	Year 2005 Base Unit Rate (S$) P_0 for Bill Re-pricing
2.	Concrete work	7	
3.	Formwork	5	
4.	Reinforcement	5	
5.	Steelwork	5	
6.	Brickwork and blockwork	4	
7.	Roofing	4	
8.	Woodwork and metalwork	7	
9.	Plumbing	8	
10.	Electrical work	3	
11.	Finishings	10	
12.	Glazing	1	
13.	Painting	3	
	Total	68	

As the start of the second stage where it involves establishing the weights of the three types of non-residential buildings using the value of contracts awarded between 1996 and 2005, relevant information is extracted from the website of BCA. The derived weights for commercial buildings (N1), industrial buildings (N2) and institutional buildings (N3), respectively, are shown in Table 4.

Table 4: Derived Weights for Non-Residential Buildings

Type of Building	Total Value of Contracts Awarded (1996 to 2005) in S$ million	Ratio/Weight
Commercial	13151.18	0.195592
Industrial	28954.43	0.430626
Institutional	25132.37	0.373782
Total	67237.98	1

9. SUMMARY

The concept of constructing a national-level Whole-Life Cost Index for buildings is new. It is an index which measures the actual costs incurred by the building owner. It can be defined as an index that measures the relative change in building ownership costs over time, relative to a base period. Singapore has yet to have a whole-life cost index for buildings and developing one is timely in view of the rapidly growing interests in sustainable design and performance of buildings. The concept and methodology proposed here is similar to the ones adopted by the BCA to construct the National BTPI for Singapore's Construction Industry which started in 1990.

While the study targets Green Mark certified buildings, it does not exclude non-Green Mark buildings if good/complete data is available. The assumption which the study uses is that Green Mark certified buildings would be the source for reliable data, especially on the building's operating costs. The Green Mark Scheme has a re-certification process which requires building owners to keep proper records of the operating costs of the building.

The proposed Whole-Life Cost Index is a forward-looking index series despite being able to only cover about 13% of all the buildings in Singapore at the present time. As the number of Green Mark certified buildings continues to grow, it would be able by 2030 to cover at least 80% of all buildings in Singapore.

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DEVELOPING A FRAMEWORK TO EVALUATE INDOOR ENVIRONMENTAL QUALITY (IEQ) PERFORMANCE OF INDUSTRIAL BUILDINGS IN SRI LANKA

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ABSTRACT

Indoor Environmental Quality (IEQ) can be considered as one of the main measure of total building performance. Even though there are various methods to evaluate IEQ of buildings, it is evident that there is no holistic approach, which considers every possible parameter which results in a more pragmatic and operational, mechanism especially for industrial buildings. Similarly in Sri Lanka, there is no comprehensive framework applied in buildings to evaluate IEQ performance and the situation is same with other countries as there is less regard to IEQ factors in measuring building performance. The industrial buildings also lacks total IEQ performance methods being utilised, however there are few which are only based on IEQ measurements such as indoor air quality, thermal, acoustic and lighting comfort.

When considering the global view, are some evaluation methods or techniques which are being used. However for the industrial buildings there are no methods with a holistic approach. This creates the need to identify existing IEQ practices with respect to industrial buildings in order to develop a comprehensive evaluation framework for total IEQ performance of industrial buildings.

Therefore, this paper attempts to establish the indicators and sub indicators proposed for the framework to evaluate IEQ performance of industrial buildings based on preliminary investigation and literature survey as part of an on-going research project. The available IEQ techniques have been identified which needs to be validated in the next step of this research study.

Keywords: *Building Performance; IEQ Indicators; Indoor Environmental Quality; Industrial Buildings.*

1. INTRODUCTION

The Indoor Environmental Quality (IEQ) performance of buildings directly or indirectly affects to the building operations and its occupants (Heinzerling *et al.,* 2013). Furthermore, the occupant acceptance regarding the perceived IEQ was correlated with four main environmental factors as thermal comfort, Indoor Air Quality (IAQ), acoustic level and illumination level (Wong *et al.,* 2009). Today, the concept of an acceptable IEQ (IEQ) is considered as an integral part of the total building performance approach, however it is not fully appreciated yet (Wong *et al*., 2009). Further, it is highlighted that there is an emerging issue of impact on IEQ related factors on the industrial building occupants (Smith and Bristow, 1994).

Moreover, conventional studies on IEQ practices evaluation only address each of the main indicators separately (Wong *et al.,* 2008). According to a study by Heinzerling *et al.,* (2013), the literature findings confirm that there is no systematic evaluation technique for accurate assessment of the whole building IEQ performance. Similarly in Sri Lanka, there is no comprehensive framework applied in buildings to evaluate IEQ performance. The situation is same with other countries as there is no high regard on the IEQ factors in building performance (Mallawarachchi and Silva, 2012). The case is true for Industrial Buildings. This creates the need to identify existing IEQ practice in case of industrial buildings in order to develop a comprehensive evaluation framework for total IEQ performance for industrial buildings.

Therefore, it is important to identify each and every sub indicator which are relating to key indicators as IAQ, thermal comfort, acoustic comfort and lighting comfort for the evaluation of IEQ performance.

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Accordingly, the ultimate aim of this research paper is to identify indicators affecting to IEQ performance while the aim of the whole research is to develop an IEQ evaluation framework for the industrial buildings. The scope of this research paper is to development of a framework for evaluating IEQ performance of the industrial buildings. This study was focused and limited only to apparel manufacturing garments in Colombo metropolitan area.

2. CONCEPT OF INDOOR ENVIRONMENTAL QUALITY

Nowadays, the concept of Indoor Environment Quality (IEQ) is merging as a new and very useful index for the total building performance (Catalina and Iordache, 2011). Further, it is a well-documented fact that people spend most of their day to day time indoors and various aspects of the indoor environment affect the occupant's well-being and performance (Prakash, 2011). Furthermore, the quality of the indoor environment reflects on the health, comfort and productivity of occupants in buildings (Singh, 1996). In addition, it had been found that even though the buildings meet the recommended standards, the occupants often complained for various parameters, such as day lighting and thermal comfort which contributed to better IEQ. It also, had a positive effect on the occupant's perception of productivity and performance (Prakash, 2011).

Thermal comfort, lighting quality, acoustical quality and air quality are the most important and main factors of IEQ (Mahbob *et al.,* 2011). All these mentioned aspects of the indoor environment interact with each other and may have consequences on the overall indoor comfort and building energy consumption (Catalina and Iordache, 2011). Standards dealing with IEQ have been developed to define the acceptable ranges of these parameters and even though the requirements of these standards are met, not all building occupants are satisfied with the indoor environment (Frontczak and Wargocki, 2011).

It was also found that each of the IEQ parameters is important and a good value of IEQ improves working conditions and minimises complaints from the occupants (Catalina and Iordache, 2011). Further, increasing interest in this field has put additional pressure on the research community as architects, engineers, facility managers, building investors, health officials, jurists, and the public seek practical guidelines on creating a safe, healthy, and comfortable indoor environment (Kumarand Fisk, 2002). Because of this, there is a greater demand for improvements in the indoor environment which intern requires changes to building design, operation, maintenance, and occupancy (Fisk, 2000).

The following categories broadly influence the IEQ and these categories operate cumulatively and their cocktail effect contributing as a risk factor to the health in the indoor environment:

- Design and construction factors
  - Office design and layout, poor lighting and ventilation scheme, ergonomics
- Environmental factors
  - Odour, lighting, temperature, dust, noise, outdoor and indoor environment
- Perceptual and psychological factors
  - Hysteria and stress due to lack of privacy, or because of lack of control or claustrophobic effects due to sealed construction
- Cultural and organisational factors
  - Cleanliness, maintenance, management and their relationships with occupants (Singh, 1996)

2.1. KEY INDICATORS AFFECTING TO INDOOR ENVIRONMENTAL QUALITY (IEQ)

Overall satisfaction and perception of indoor environment, being a subjective evaluation, can be impacted by various contextual factors (Jonson and Wilhelmsson, 2012). Figure 1 indicates the main four indicators which are affecting to IEQ performance.

Figure 1: Main Indicators of IEQ

2.1.1. ACOUSTIC COMFORT

All sounds that are distracting, annoying, or harmful to everyday activities such as work, rest, study and entertainment can be regarded as noises (Lai *et al*., 2009). Noise and vibration in a wave motion can be a discomfort in terms of psychological and can come from outdoors, engineering services. Further, the noise pollution can create stressful feelings and health effects such as dizziness in humans (Mahbob *et al.*, 2011). The acoustic comfort also relates to the ability of the building to provide an environment with minimal unwanted noise (Ncube and Riffat, 2012).

2.1.2. LIGHTING COMFORT

Light can influence the building occupants' comfort level in several ways through vision. It is really important towards the productivity. Poor quality in lighting can cause fatigue, drowsiness, nausea, eye irritation etc. Poor lighting can be because of excessive lighting or inadequate of lights (Mahbob *et al.*, 2011). When considering the acceptable lighting level at various places, general Office illumination levels should be at least 500 lux and the colour rendering index should range from 60 to 80 lux (Ncube and Riffat, 2012). There are number of available guides and codes of practices which provide recommendations on adequate indoor lighting designs (Lai *et al.*, 2009). According to the guidelines and code of practices, an illumination level of 2000 lx with a colour rendering index not less than 90 is required for a fabric inspection factory while 500 lx with a colour rendering index range is from 60 to 80 should be maintained in a general office (Ncube and Riffat, 2012).

2.1.3. INDOOR AIR QUALITY (IAQ)

IAQ is one of the major contribution factors in determining the IEQ level (Mahbob *et al*., 2011). It was found that over the past decades, exposure to indoor air pollutants is believed to have increased due to a variety of factors, including the construction of more tightly sealed buildings, the reduction of ventilation rates (for energy saving), and the use of synthetic building materials and furnishings as well as chemically formulated personal care products, pesticides and household cleaners (Wong *et al.,* 2008). However, investigating all types of indoor air pollutants for general air quality monitoring and assessment is a very complicated matter (Mui *et al.,* 2008). There have been growing concerns in the past decade over complaints attributed to poor indoor air quality (IAQ). Various environmental parameters have been suggested for IAQ assessment (Chao e*t al.*, 2001). In a country which has a hot-humid tropical climate like, the wind or the air flow is required to accelerate the evaporation so that the discomfort of stickiness of the skin can be reduced (Nasir *et al.*, 2011). Present surveys prove IAQ play an important role and has a strong and direct correlation with work efficiency output of individual workers (Mahbob *et al.*, 2011).

2.1.4. THERMAL COMFORT

Thermal comfort can be described according to air temperature, air velocity, and relative humidity and can be expressed by the building user perception whether they want it to be cooler or warmer to be comfortable

(Mahbob *et al.*, 2011). In order to determine thermal comfort level in workplace, individual factors such as gender, activity before they enter the building and the age plays important roles that will contribute to environment satisfaction (Mahbob *et al.*, 2011). Besides, the effective temperature for thermal comfort was found to be around 26.1°C and will differ according to race, age. However, the sex did not influence the perception of thermal comfort (Mui *et al.*, 2008). Although there are few of the studies conducted previously any of them, did not acknowledge the influence of age, gender, physical conditions and educational level towards thermal comfort perceptions. More work is required for other "non-thermal" parameters which affects thermal comfort (Kwong *et al.*, 2014). Three factors contributing to the increase in temperature in a building are as follows: (Nasir *et al.*, 2011)

- Emission of heat from the lights and electrical appliances
- Heat gain from the outside through the walls, windows and roofs of the buildings
- Heat convection by hot air from outside the building

3. IEQ EVALUATION TECHNIQUES

There are many environmental methodologies and methods for evaluating environmental performance of buildings (Sinou and Kyvelou, 2006). The assessment of any building development should touch the aspect of "Holistic Health" of the built environment which would include all aspects of people's needs and functions, in terms of physical, emotional as well as social health. Further, to minimise pollution effects from building materials, moulds, and dampness and glare that would cause adverse impact on the occupants (Kim and Kim, 2010). As a result of information arising from such studies, various models have emerged that seek to assess or measure these factors by various researchers (Kamaruzzamana *et al.*, 2011). These schemes invariably incorporate assessments relating to a number of attributes of IEQ (IEQ) and each of which carries credit points to contribute to the overall result (Kamaruzzamana *et al.*, 2011). Some of the numerous buildings' environmental evaluation tools which are corresponding to the various methodologies are recently developed, conducted detailed and thorough assessments, which seem to provide reliable results (Sinou and Kyvelou, 2006).

3.1. MULTIVARIATE REGRESSION ANALYSIS

Workplace variables inducing the largest number of health symptoms, comfort or odour concerns were investigated by multivariate regression analysis (Kim and Kim, 2010). It was realised that successful control of the indoor environment requires an understanding of the integral indoor environmental parameters and also the occupants' acceptance of the four basic IEQ components for an office environment (Wong *et al.*, 2008). Further, mathematical expressions were proposed for the overall IEQ acceptance using a multivariate logistic regression model, which can be used as a quantitative measure for an office environment design (Lai *et al.*, 2009).

3.2. IEQ EVALUATION TOOLS

Finding accurate, easy-to-use, and inexpensive measurement equipment is one of the major hurdles in IEQ performance evaluation (David *et al.*, 2013). With the explosion of wireless monitoring equipment in recent years, measuring various building parameters has become a much less labour-intensive process (Mui and Chan, 2005). However, there are still a number of operational hurdles that still make measurement, a cumbersome process (Benton *et al*., 1990). While sensor and logging device manufacturers have made products that are increasingly accurate and easy to use such as wireless, the work of creating devices with multiple sensors is still largely in the hands of the users. IEQ measurement requires a combination of devices and individual sensors to capture the state of IEQ in a space (Chiang *et al.*, 2001). Further, data logger and electronic sensors typically used in evaluation of thermal comfort (Kwong *et al.*, 2014).

3.3. GREEN BUILDING TOOLS

For enhancing building environmental performance, many voluntary assessment schemes have emerged, such as the Leadership in Energy and Environmental Design (LEED) of the US, the Building Research

Establishment Environmental Assessment Method (BREEAM) of the UK, and the Green Star of Australia GB Tool Method, CASBEE Method, HQE Method, VERDE Method, SCATS, CBE (Liang *et al.*, 2014). All such schemes invariably embrace assessments on a number of IEQ (IEQ) parameters and each of which carries certain credit points to the overall result (Lai and Yik, 2009). Table 1 presents the indicators of IEQ, which are addressed in green building tools.

Table 1: Indicators of IEQ Addressed by Various Tools

IEQ Related Parameters Involved	Tools						
	GB Tool Method	**LEED Method**	**CASBEE Method**	**HQE Method**	**VERDE Method**	**SCATS**	**CBE**
Day lighting	×	×		×			
Air Ventilation Speed				×		×	
CO2	×					×	
Relative Humidity		×				×	
Illumination		×	×			×	
Indoor Air Quality		×			×		×
Ventilation		×					
Air Temperature		×				×	
Air Quality			×				
Noise / Acoustics		×	×	×	×	×	×
Thermal Comfort			×		×		×
Lighting			×	×	×		
Visual Quality							×

4. VARIOUS PARAMETERS INFLUENCING IEQ PERFORMANCE

Some of the present surveys show acoustic and lighting stand in the lowest ranking of IEQ parameters, compared to IAQ and thermal comfort due to less complaints (Mahbob *et al.*, 2011). But, some other research studies were orientated only towards the impact of glazing on the energy consumption and thermal comfort (Catalina and Iordache, 2011) deliberated whether overall satisfaction can be described by stable relative weights of different aspects of indoor environment and concluded that generally level of thermal and air quality is more important than lighting and humidity; however, relative weights can differ between occupants, depending on their requirements (Humphreys, 2005). In another thermal comfort study conducted, it was concluded that the air temperature, wind velocity and solar irradiance were significant aspects that influenced the occupants' thermal sensations while relative humidity; acoustic, lighting and indoor air quality had no statistical importance (Hwang *et al.*, 2006). It was stated in another research that, while thermal comfort, indoor air quality and visual environment are of comparable importance, aural environment is the major determining factor (Lee *et al.*, 2012). But, correlations have the same range of magnitude, indicating that all 4 main environmental parameters are equally important for the assessments of the overall indoor environment and contribute equally much to the overall acceptability if only their acceptability levels are similar is stated in another research (Monika *et al.*, 2012). Based on the total votes, both thermal and aural environmental qualities were deemed the most important contributors whereas indoor air quality was considered the least (Lai *et al.*, 2009).

5. SUMMARY OF BUILT ENVIRONMENT RELATED FACTORS INFLUENCING IEQ PERFORMANCE

According to the Table 2, summarisation of the 20 present researches on IEQ show that, there are various sub indicators which are affecting to overall IEQ performance has been identified. But, most of the research studies were orientated only toward the specific set of indicators and none of those addressed each and every indicator affecting to IEQ.

Table 2: Indoor Environmental Quality Indicators

	Indoor Environmental Quality Indicator	**References (Shown in below)**																			
		01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	IAQ	×													×	×			×	×	
1.	CO Concentration																		×		×
2.	CO_2 Concentration	×		×	×		×			×		×	×		×			×	×		×
3.	CO_3Concentration																		×		×
4.	Dust					×															
5.	Fresh Air Supply (Ventilation Rate)	×	×																	×	×
6.	Moisture Level																			×	
7.	Odour				×																
8.	Perceive Air Quality	×	×																		
9.	Relative Humidity (RH)	×	×	×			×	×		×		×	×		×		×	×	×		
10.	Relative Air Velocity	×								×			×		×						
11.	Smell		×													×				×	
12.	Volatile Organic Compound					×	×					×			×			×	×		
13.	Water Vapour Pressure	×																		×	
	Lighting Quality	×				×		×	×		×					×	×	×		×	
14.	Colour Rendering Index	×	×					×	×		×				×	×					
15.	Day Lighting Factors	×	×	×							×	×			×	×					×
16.	Distance from Window		×					×												×	
17.	Flicker Rates	×										×									×
18.	Glare	×	×	×			×	×							×			×		×	×
19.	Illuminance	×		×	×		×	×		×		×	×	×	×	×			×	×	×
20.	Illumination Uniformity	×																			
21.	Luminance Distribution	×					×		×												

	Indoor Environmental Quality Indicator	References (Shown in below)																			
		01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
22.	Rendering And Appearance (Colour Characteristics)	×																			
23.	Room Surface Reflectance	×																			
24.	Wall Colour								×					×		×					×
	Thermal Comfort	×	×	×	×	×	×	×	×	×	×		×	×	×			×			
25.	Dew Point Temperature	×																			
26.	Air Temperature	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×				
27.	Mean Radiant Temperature	×		×						×											
28.	Occupants Metabolic Rate								×												×
29.	Surface Temperature of Clothing	×																			
30.	Thermal Resistance of Clothing	×											×								×
	Acoustic Quality			×		×	×	×	×	×	×	×	×	×	×	×	×	×		×	×
31.	Sound Insulation			×								×									×
32.	Outdoor Traffic Noise											×									
33.	Equipment and Mechanical Noise											×									
34.	Overhearing Private Conversation											×									
35.	Excessive echoing of voices/sounds											×									

1- (Ncube and Riffat, 2012) **2**- (Kamaruzzamana *et al*, 2011) **3**- (Liang *et al*, 2014) **4-** (Wong, 2008) **5**- (JonssonandWilhelmsson , 2013) **6**- (Choia *et al*, 2010) **7**- (Mahbob *et al.*, 2011) **8**- (Kim and Dear, 2012) **9**- (Lee *et al*, 2012) **10**- (Monika *et al*, 2012) **11**- (Abbaszadeh *et al*, 2006)**12**- (Lai *et al*, 2009) **13**- (Chiang *et al*, 1999) **14**- (Chianga and Lai, 2002) **15**- (Frontczak M. , 2011) **16**- (Mydin *et al*, 2012) **17**- (Sulaiman *et al*, 2013) **18**- (Fadeyin *et al*,2014) **19**- (Nasir *et al*, 2011) **20**- (Steskens and Loomans, 2010)

When considering as a whole, there are some indicators which were addresses by majority of the survey studies such as CO_2 concentration, Relative Humidity (RH), relative air velocity, day lighting factors, glare, illuminance and air temperature while some other factors are addressed in only one or few research studies such as CO, CO_3, dust, moisture level, perceive air quality, illumination uniformity, rendering and appearance (colour characteristics), room surface reflectance, dew point temperature, surface temperature of clothing, thermal resistance of clothing, outdoor traffic noise, equipment and mechanical noise, overhearing private conversation and excessive echoing of voices/sounds.

6. APPLICATION OF BUILDING PERFORMANCE AND IEQ EVALUATION IN SRI LANKA

Applicability of Building Performance Evaluation concept is rare in the Sri Lankan context. When considering about the researches that have been conducted related to BPE, Linkesan (2003) has carried out a research to evaluate the performance of school buildings in Sri Lanka using a post occupancy evaluation, and (Kiritharan, 2002) has carried out a POE to evaluate the performance of residential apartments in Sri Lanka.

Even though the application of BPE techniques in the Sri Lankan context is very low; there is a high demand for it in the hotel industry. The use of Building environmental performance assessment methodologies such as LEED and BREEAM (eg: Aitken Spence hotels) are considered as a plus point of attracting customers to their industry (Konara, 2009).

The preliminary investigations which was carried out by getting opinions from the industry practitioners revealed that in Sri Lankan context, there is a requirement for evaluating basic parameters with respect to IEQ in garment industry buildings using the lux level, dust level etc., However, these surveys are not done in a serious manner and are done for the compliance of the Factory Ordinance. Normally, these surveys are conducted by the department of Labour.

According to a study by Heinzerling *et al.,* (2013), the literature findings confirm that there is no systematic evaluation technique for the accurate assessment of whole building IEQ performance. It is further verified by Adebiyi *et al.,* (2007), as there is no generally agreed model for IEQ evaluation. Consequently, a critical need exists to develop an IEQ performance evaluation framework to define acceptable IEQ levels for buildings and to provide standard way to doing continuous improvement of IEQ (Kumar and Fisk, 2002).

7. CONCLUSIONS

This study explores the factors affecting to IEQ which is a major part of total building performance. The literature review was done on the indicators and sub indicators of IEQ and current techniques regarding the evaluation of IEQ performances. According to the industrial practitioners, holistic approach to evaluate IEQ by considering each and every parameter needs to be considered, especially in the industrial sectors such as the garment manufacturing buildings as IEQ directly relate to the occupancy satisfaction and productivity of the occupants.

Based on the literature finding, development of a conceptual framework will be done by based on the four major indicators and their sub indicators. It is proposed to carry out a survey, which will indicate the relative importance of sub indicators through the opinion of industrial practitioners and AHP tool will be used to analyse the data.

It is perceived that the ultimate results study can be used for the evaluation of the IEQ of industrial buildings and also report the existing situation in the Sri Lankan context. Further the findings can be used for continuous improvement in IEQ of industrial buildings in Sri Lanka.

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DEVELOPING A TBPE SCORING FRAMEWORK FOR ASSESSING TOTAL BUILDING PERFORMANCE

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ABSTRACT

Building Performance Evaluation (BPE) has received an increasing attention over the past two decades among the researchers to provide a comfortable and stable internal environment to increase and provide a better human potential. To determining how well the facilities are performing in order to support the organisational goals and user requirement, it is vital to conduct regular building evaluations which provide the current status quo of the building. Aiming to this, there are various BPE approaches developed around the world, and as evidenced there are no in-depth studies on Building Performance Evaluation (BPE) in tropical countries to evaluate the building performance. However, adapting these approaches might not necessarily be applicable in the context of tropical countries due to geographical, climatic, cultural and other differences. This has been identified as the gap in this research and aimed to formulate a holistic Total Building Performance Evaluation (TBPE) scoring framework, for the assessment of performance of buildings. First, a comprehensive literature survey was carried out. This was followed by an expert survey to sieve out the most significant BP factors identified in the literature survey. With that detailed questioner survey was carried out proposing a TBPE scoring framework compromising total of two hundred and sixty five points to evaluate buildings with 7 criteria and 57 dimensions in which energy management, reachability to the building, occupational hygiene, thermal comfort, unit costs savings, load bearing capacity etc had higher contribution in evaluating building with relation to tropical context. Finally, this paper readdresses the need of evaluating the buildings and suggesting the paradigm to evaluate the buildings in an objective manner.

Keywords: *Building Performance; Building Performance Evaluation; Total Building Performance Evaluation.*

1. INTRODUCTION

People spend more than 90% of their time indoors and buildings are the facilitators of organisational performance in order to provide a comfortable and stable internal environment to increase and provide a better human potential (Amaratunga and Baldry, 1998). According to Barrett and Baldry (2003) for organisations to know how well their facilities are supporting organisational goals and user requirements, the organisations should introduce regular building evaluations. Where building evaluation is considered to be the first priority as it provides the current status quo of the building, before anyone can effectively predict future performance (Wong and Jan, 2003). Building Performance Evaluation (BPE) is, therefore, has become the key to determine the effectiveness of a built facilities performance in a comprehensive manner (Douglas, 1996; Lavy *et al*., 2010).

Steinke *et al*. (2010) indicated that the BPE becomes an integral part of all facility capital projects in a way that aligns facilities with larger organisational strategies and ultimately provides feedback for overall decision making. This was also stated by Pullen *et al*. (2000) the current state of the art indicates a need to develop integrated key performance indicators for facilities, seeking links between performance, maintenance, operations and energy expenditure and cost-effectiveness.

Thus, this research is focused to develop a TBPE scoring framework for the buildings in tropical countries. The discussion of paper begins with an introduction to the study followed by a critical literature review, brief of research methodology and proposing a Total Building Performance Evaluation (TBPE) scoring framework.

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2. LITERATURE REVIEW

The term Building Performance (BP) trace back from BC 1955 (Preiser and Vischer, 2005). The term formally originated from the introduction of Post Occupancy Evaluation (POE) in 1960 (Preiser and Vischer, 2005). In the past two decades, organisations have started to look at their buildings not just as a way to house people and activities, but also as a way to fulfil strategic objectives (Amaratunga *et al*., 2000; Brackertz, 2006; Steinke *et al*., 2010). Thus, Steinke *et al*. (2010) argued that the traditional POE does not provide the type of feedback needed to assess these strategic organisational outcomes.

Thus, the BPE has become an effective approach to assess the strategic organisational outcomes (Preiser and Vischer, 2005; Steinke *et al*., 2010). The BPE framework was developed in order to broaden the basis for POE feedback to include a wider range of stakeholders and decision-makers who influence on buildings (Preiser and Vischer, 2005). Preiser and Wang (2006) stated that BPE provides systematic "consumer feedback" on what works and what does not work in a building, thus helping to improve its performance. Furthermore, they argued that in building performance evaluation, the entire building delivery and life cycle is considered, ranging from early strategic planning, programming, design, and construction to occupancy, and eventually to the recycling or adaptive reuse of redundant facilities. As such, there are various techniques developed under different context. Among them checklist appraisal approach, architectural feasibility, matrix method, Orbit-2, Orbit-2.1, Building In Use (BIU), Building Quality Assessment (BQA) and Serviceability Tools and Methods (STM) could be named such.

Checklist appraisal approach is a common expert method while architectural feasibility approach is designed to determine whether a client organisation should remain in the building or to renovate it or to move to a different building (Becker, 1990). Matrix approach on the other hand is much in common with checklist appraisal approach which is evaluated by an expert using a checklist (Becker, 1990). Orbit-2.1 and Orbit-2 are two different approaches which differ in four ways where the original seventeen key issues were reduced to fourteen in Orbit-2.1. Further Becker, (1990) argues that Building-in-Use (BIU) approach is more systematic rather than an analytical approach of yielding information about people and buildings. Moreover, Building Quality Assessment (BQA) approach is essentially a tool for assessing what a building provides in terms of facilities. Serviceability Tools and Methods (STM) is another approach designed to bridge between functional programs written in user language on one side, and outline specifications and evaluations written in performance language on the other (Baird *et al*., 1996).

A well-conceived and well directed BPE approach can be extraordinarily effective in delivering real benefits to the building owners, managers and occupants (Baird *et al*., 1996). As illustrated by Baird *et al*. (1996) significant virtues of conducting a BPE are; better matching of demand and supply, improved productivity within the workplace, minimisation of occupancy costs, increased user satisfaction, certainty of management and design decision making, higher returns on investment in buildings and people, incentives for innovation and the development of alternatives. In the process of developing the BPE approaches there are some key general requirements should be considered (Jiun, 2005).

- Methodological transparency which means it should allow access and understanding of assumptions
- Focus on performance which describes that it should be as far as possible fully performance based and quantifiable
- Easily accessible measures which denotes that BPE's parameters should be easily measured and accessed
- Measures as a whole which means that the scope of assessment should not focus solely on one narrow aspect of building performance such as cost or energy efficiency
- Facilitate benchmarking describes the approach developed should able to facilitate the comparison of performance between different buildings for different organisations at different times

The characters mentioned above are some of the main requirements that should be adequately considered and addressed when developing a BPE approach. This led people to demand more from the buildings thus resulting in the heightened expectations of building performance as a whole (Steinke *et al*., 2010). In view of these requirements, BPE has been well established as a concept in recent years to facilitate and evaluate the buildings relating to the purpose it is indent for. But as for tropical countries the applicability of BPE concept and its approaches are still at the early stages. Financial measures such as annual maintenance costs per employee, cleaning costs per square metre, energy consumption per square metre, etc. are the most commonly used building performance criterions in tropical countries like Sri Lanka (Konara and Sandanayake, 2010). The most eligible motive for the concept of TBP and various BPE approaches have not become widespread among the tropical countries private or public sectors because of the unawareness of the building owners, facilitators and users regarding the merits of evaluating the performance of a building and at the same time reactive approaches of the building owners towards managing and maintaining the buildings they occupy.

Konara and Sandanayake (2010) further demonstrates that the TBP is not considered, rather the organisations in tropical countries such as Sri Lanka evaluate the performance of elements, components, materials and equipment of the building separately through annual maintenance assessments. TBP is not assessed in tropical countries and therefore as argued by Douglas (1996) that the predictability of TBP is relatively low. Thus building evaluations that continue in singular areas with recommendations for actions that will solve the performance problem are going to create more problems. Therefore, the process of evaluating building performance consumes a considerable amount of resources (such as time, money, labour) which has been contributed positively to the reactive nature of the building owners evaluating the TBP.

Hence, a building's performance can be judged on an almost infinite variety of criteria such as financial organisational issues, space use efficiency, performance or productivity, information technology etc. (Becker, 1990). In that sense, TBP studies can be seen as a whole building evaluation approach, which addresses the performance evaluation as a whole. Thus, seven criteria namely occupants comfort and health, sustainable, economic, process and growth, leadership and management, functional and technical, performances were encountered to develop the proposed TBPE scoring framework (Lützkendorf *et al*. 2005). The next section of this paper outlines the carried research methodology for this study.

3. RESEARCH METHODOLOGY

The survey research approach was selected for this research and three steps were adopted to develop the TBPE scoring framework as shown in the Figure 1.

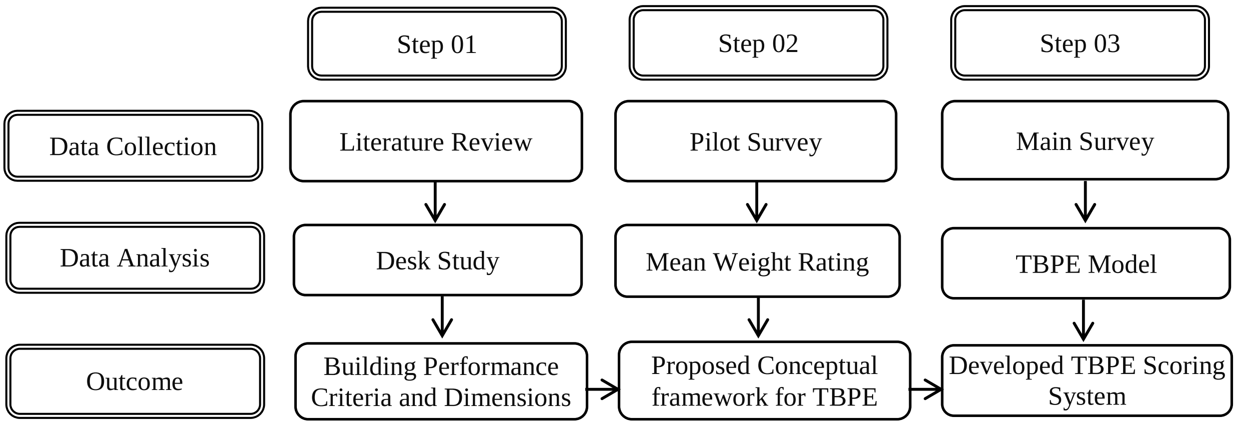

Figure 1: Steps in the Research Methodology

Step 1: A comprehensive literature review was conducted to explore the concept of BPE, BPE requirements, existing BPE approaches to identify the relevant BP criteria and dimensions through referring books, journal articles and unpublished dissertations.

Step 2: Pilot survey was carried out among five industry experts and analysed using Mean Weighted (Eq: 01) in order to sieve out the most significant and fundamental BP criterions and dimensions to derive with a conceptual framework for the development of TBPE scoring framework which are relevant to the tropical countries.

$$M = \frac{\sum (V_i x F_i)}{n} \quad \text{(Eq: 01)}$$

Where, M = mean weighted rating, V_i = rating given by the respondent, F_i= frequency of responses, n = is total number of responses.

Step 3: The proposed conceptual TBPE framework consisting of seven performance criteria and its fifty seven dimensions (Table 1) were developed using the literature review and the pilot survey findings.

4. PROPOSED TBPE SCORING FRAMEWORK

The proposed values of TBPE framework were constructed using linear factorial approaches as follows (Eq: 02).

$$P = \sum_{i=1}^{7} C_i \quad \text{(Eq: 02)}$$

Where P = TBP score of the building; C_i = (where i = 1, 2, 3….7.) denotes the criteria's total score and to deploy the (C_i) criteria's total score, it is derived through;

$$C_i = \sum_{i=1}^{n} D_i \times q \quad \text{(Eq: 03)}$$

Where D_i = (where i = 1, 2, 3…, n) denotes the i^{th} criteria's dimension's score, and q = {R / 0, 0.25, 0.5, 0.75, 1} denotes the parameters rated by decision maker for the dimensions performance level (adapted based on the model suggested by Hong, 2007) and where R = denotes the real number. Further, to determine the score for each dimensions (D_i) it is obtained through;

$$D_i = KW_i \quad \text{(Eq: 04)}$$

Where W_i = rank reciprocal weight of the i^{th} dimension, and K = a constant numerical value is determined based on assigning score 1 to the least important dimension (adapted based on the model suggested by Hong, 2007). Whereas W_i of each dimension is derived by using;

$$W_i = \frac{\frac{1}{R_i}}{\sum_{i=1}^{57} \frac{1}{R_i}} \quad \text{(Eq: 05)}$$

Where R_i = (where i = 1, 2, 3 …., 57.) denotes the i^{th} dimension's rank. Whereas the R_i rank for each dimension could be rank by deriving with an overall performance weightage (OPW) where the least OPW was provided with a least ranking and whereas the maximum value of OPW of the i^{th} dimension was ranked first (adapted based on the model suggested by Kamarazaly, 2007). Thus, OPW can be deployed using;

$$X_{i,k} = I_i \times M_{i,k} \quad \text{(Eq: 06)}$$

Where $X_{i,k}$= Overall Performance Weightage (OPW) of the k^{th} dimension of the i^{th} criteria, I_i = Relative Important Index (RII) of i^{th} criteria, $M_{i,k}$ = mean weighted rating of k^{th} dimension of i^{th} criteria which can be formulated using the Equation 1.Whereas the RII of i^{th} criteria is thus used to derive with;

$$I_i = \frac{\sum W}{AN} \quad \text{(Eq: 07)}$$

Where; W = Weighting to each criteria by the respondent, A = highest weight, N = total number of samples (The relative importance index range from 0 to 1).

Table 1: Proposed TBPE Factors

Functional Performance	OC and Health Performance	Process and Growth Performance	Technical Performance	Economic Performance	L and M Performance	Sustainable Performance
▪ Space suitability and usability	▪ Level of cleanliness	▪ Failure response rate	▪ Ease of maintenance	▪ Preference on WLC costs	▪ Number of training on BP	▪ Energy management
▪ Space clarity	▪ Thermal comfort level	▪ Fire safety plan	▪ Load bearing capacity	▪ Unit costs savings	▪ Making right decisions	▪ Environmental loading
▪ Service life	▪ Availability of PPA equipment	▪ Maintenance of past data	▪ Thermal protection of envelope	▪ Additional income stream	▪ Managing and controlling resources	▪ E-Procurement policy
▪ Signage, way finding performance	▪ Occupational hygiene	▪ Security plan	▪ Technology efficiency	▪ CSR expenditures	▪ Interest and ethical behavior of staff	▪ Selection of environmental friendly materials
▪ Site amenities	▪ Level of olfactory comfort	▪ Maintenance of hazardous materials	▪ Structural stability	▪ Return on Investment (ROI)	▪ Level of accountability of the service provided	▪ Waste management
▪ Level of expression for values of service	▪ Internal and external communication	▪ Sustainable design process in planning and renovation process	▪ Durability of elements		▪ Determine the type of care andservices	
▪ Site sustainability	▪ Room acoustics	▪ Benchmarking	▪ Availability of occupancy sensors		▪ No. of awareness programs conducted	
▪ Level of flexibility	▪ Noise isolation	▪ Management of building service				
▪ Cultural, recreational value of site	▪ Ventilation effectiveness	▪ Monitoring of technical systems				
▪ Aesthetics, appearance of building	▪ Glare control					
▪ Provision for disabled in building						
▪ Reachability to the building						
▪ Occupancy density						
▪ Design efficiency						

The quantitative values for BP factors in TBPE framework were established through the equation which is presented in Table 2 (where, R = ranking of factors, W_i = rank reciprocal weight of factors and D_i = scores for each factors).

Table 2: TBPE Scoring Framework

	Total Building Performance Factors	R_i	W_i	D_i
	Functional Performance			**62**
FP-1	Space suitability and usability	10	0.0215	6
FP-2	Space clarity	33	0.0065	2
FP-3	Service life	7	0.0307	8
FP-4	Signage, way finding performance	21	0.0102	3
FP-5	Site amenities	31	0.0069	2
FP-6	Level of expression for values of service	21	0.0102	3
FP-7	Site sustainability	36	0.0060	2
FP-8	Level of flexibility	28	0.0077	2
FP-9	Cultural, recreational value of site	47	0.0046	1
FP-10	Aesthetics, appearance of building	43	0.0050	1
FP-11	Provision for disabled in building	53	0.0041	1
FP-12	Reachability to the building	2	0.1075	29
FP-13	Occupancy density	53	0.0041	1
FP-14	Design efficiency	21	0.0102	3
	Occupants Comfort and Health Performance			**54**
OH-1	Level of cleanliness	20	0.0107	3
OH-2	Thermal comfort level	4	0.0537	14
OH-3	Availability of PPA equipment	51	0.0042	1
OH-4	Occupational hygiene	3	0.0717	19
OH-5	Level of olfactory comfort	24	0.0090	2
OH-6	Internal and external communication	24	0.0090	2
OH-7	Room acoustics	37	0.0058	2
OH-8	Noise isolation	34	0.0063	2
OH-9	Ventilation effectiveness	11	0.0195	5
OH-10	Glare control	17	0.0126	3
	Technical Performance			**27**
TP-1	Ease of maintenance	14	0.0154	4
TP-2	Load bearing capacity	6	0.0358	10
TP-3	Thermal protection of envelope	14	0.0154	4
TP-4	Technology efficiency	19	0.0113	3
TP-5	Structural stability	56	0.0038	1
TP-6	Durability of elements	57	0.0038	1
TP-7	Availability of occupancy sensors	14	0.0154	4
	Process and Growth Performance			**18**
PP-1	Failure response rate	18	0.0119	3
PP-2	Fire safety plan	38	0.0057	2
PP-3	Maintenance of past data	13	0.0165	4
PP-4	Security plan	27	0.0080	2
PP-5	Maintenance of hazardous materials	44	0.0049	1
PP-6	Sustainable design process in planning and renovation process	55	0.0039	1
PP-7	Benchmarking	48	0.0045	1
PP-8	Management of building service	32	0.0067	2
PP-9	Monitoring of technical systems	50	0.0043	1
	Sustainable Performance			**64**
SP-1	Energy management	1	0.2150	57
SP-2	Environmental loading	49	0.0044	1
SP-3	E-Procurement policy	29	0.0074	2
SP-4	Selection of environmental friendly materials	26	0.0083	2
SP-5	Waste management	39	0.0055	1
	Economic Performance			**26**
EP-1	Preference on WLC costs	45	0.0048	1
EP-2	Unit costs savings	5	0.0430	11
EP-3	Additional income stream	12	0.0179	5

	Total Building Performance Factors	R_i	W_i	D_i
EP-4	CSR expenditures	52	0.0041	1
EP-5	Return on Investment (ROI)	8	0.0269	7
	Leadership and Managerial Performance			**15**
LP-1	Number of training conducted on BP	30	0.0072	2
LP-2	Making right decisions	9	0.0239	6
LP-3	Managing and controlling resources	35	0.0061	2
LP-4	Level of awareness programs conducted	41	0.0052	1
LP-5	Level of accountability of the service provided	40	0.0054	1
LP-6	Determining the type of care and services	46	0.0047	1
LP-7	Interest and ethical behavior of staff	41	0.0052	1

When analysing each dimensions under each criteria, six dimensions (energy management, reachability to the building, occupational hygiene, thermal comfort, unit costs savings and load bearing capacity) account for 140 points which is more than 50% of available points, while some important dimensions are rated with only one point such as structural stability, preference on WLC costs, waste management, maintenance of hazardous materials, etc. This explains the fact that the developed TBPE scoring framework to assess building performance is based on the local building professionals and building practitioners' opinions towards the importance of identified TBPE criteria and dimensions. Thus, the scoring framework (point distribution) solely based upon the building professionals' priority of these criteria at the time the survey is conducted.

Further, it is important to note that attempting the other credit requirements is also possible in the local context if desired by the building owner and the construction project team in order to achieve a good performance in building. It will increase the total number of points resulting in more environmentally sustainable buildings with prestigious TBPE scoring framework. Table 2 represents the maximum allowable scores of 64, 62, 54, 27, 26, 18 and 15 out of 265 to be distributed among sustainable, functional, occupant comfort and health, technical, economic, process and growth and leadership and managerial performance respectively. With the identified score Table 3 provides the parameters established for the purpose of distributing the score among the building performances which is provided to the building evaluator to assess in a five point Likert scale basis. Thus the TBPE can be modelled using Eq: 03 to rate the performance of the building with respect to the five point Likert scale 1 to 5 provided to the evaluator which assigned with the weights of 0, 0.25, 0.5, 0.75, and 1, which distributes the maximum allowable scores of 64, 62, 54, 27, 26, 18 and 15 out of 265 to be distributed to an allowable scores based upon the current building performance of building among sustainable, functional, occupant comfort and health, technical, economic, process and growth and leadership and managerial performance up to an acceptable level.

Table 3: Weights and Description of the Parameters

Scale	Rating for Dimension	Description	Weights Assigned %
1	NA	No such dimensions' performance is incorporated in to the building. Example; no thermal comfort followed.	0
2	P	Poorly following the dimension performance Example; no standards, technology used or followed	25
3	M	Moderately following such dimensions specified Example; standards are maintained while no new technology are incorporated	50
4	H	Highly adopting such dimensions in to the building. Example; standards are well maintained with improved technology	75
5	E	Excellently incorporated in to the building and maintained. Example; standards are excellently maintained and innovated technology are used to maintain such performance (usage of BMS to control thermal comfort)	100

5. CONCLUSIONS

A conceptual TBP framework was proposed compromising of seven criteria and fifty seven dimensions to assess building performance of tropical buildings. With the proposed conceptual TBPE scoring framework a mathematical TBPE model was derived to analysis and appropriate weights were assigned and derived with a TBPE scoring framework which was solely based upon the building professionals' priority at the time the survey was conducted.

Development of the TBPE scoring framework concluded of having a maximum allowable scores of 64, 62, 54, 27, 26, 18 and 15 out of 265 to be distributed among sustainable, functional, occupant comfort and health, technical, economic, process and growth and leadership and management performance respectively whereas it pin pointed the fact that, energy management, reachability to the building, occupational hygiene, thermal comfort, unit costs savings, load bearing capacity etc are having higher contribution on BPE with relation to Sri Lankan context.

The developed TBPE scoring framework can be further developed by identifying measurement units and parameters for each and every performance dimensions to tropical context in order to distribute the scoring, instead of asking the respondents to rate each dimension. After identifying the unit of measurements and parameters, a benchmark can be established for each and every performance dimension to standardise the scoring framework and to evaluate buildings according to the benchmarks.

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DIFFERENTIATING GREEN BUILDINGS FROM CONVENTIONAL BUILDINGS: ENVIRONMENTAL PERFORMANCE PERSPECTIVE

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ABSTRACT

In the current situation, where people concerns about sustainability environment, building occupants seek to be comfortable and productive in their workplace. Occupants with local control over their environment generally have an improvement in their work effort and productivity. However, work productivity of occupants can be de-motivated and interrupted due to poor environmental conditions. Thus, the intervention to ensure a healthy working environment should always be the first step towards improving productivity. In the governing concern on improving occupant's working environment, Green Building movement is fast becoming a necessity. It is therefore impressive that there is already emerging national consensus on the definition of a green building and a rapidly increasing number of green projects in both the public and private sectors. Green buildings can be defined in various ways however, giving definition compared to 'conventional' buildings is a supplementary problem. There is no doubt that the term has a very positive connotation. Further, green buildings generate lot of benefits to people and the environment. However, no evidence that the level of occupant comfort and satisfaction are greater in 'green' rather than conventional buildings.

Hence, this study was aimed to identify facts for differentiating green buildings from conventional buildings in terms of environmental performance. The available literature was reviewed and preliminary investigation was conducted in selected green rated and non-green buildings. The indoor environment quality criteria which is developed based on GREENSL® rating system was evaluated in selected buildings to identify differences between green and conventional buildings. According to the results of literature survey and preliminary investigation, green buildings showed high environmental performance compared to conventional buildings in terms of indoor air quality, thermal comfort and lighting quality whilst there was a less satisfaction with acoustic comfort in green buildings. However, the success of green buildings depends on the quality and efficiency of the installed green systems. The rating system can be used as the common language and standards of measurement to define green buildings, differentiating from conventional buildings.

Keywords: *Conventional Building; Environmental Performance; Green Building; GREENSL® Rating System.*

1. INTRODUCTION

An unsatisfactory physical environment can lead to occupant dissatisfaction. In the current situation, where people concerns about sustainability environment, building occupants seek to be comfortable and productive in their workplace. Further, occupants demand to have priority in terms of comfortability to use and utilise the facilities and services as it must be fit for purpose of the user (Khalil and Husin, 2009). In the governing concern on improving occupant's working environment, Green Building (GB) movement or sustainable development is fast becoming a necessity (Prakash, 2005; Singh *et al*, 2009). The benefits of GBs related to indoor environmental quality improvements are the reduction on health costs and the increase on occupants' productivity through their perceived satisfaction towards work areas (Ross and Lopez-Alcala, 2006; Edwards, 2003; Kats, 2003; Ries, 2006 cited Lacouture *et al*., 2008). It is therefore impressive that there is already an emerging national consensus on the definition of a green building and a rapidly increasing number of green projects in both the public and private sectors. Many buildings are fast moving into green buildings from their traditional phenomenon due to its social, economical and

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environmental benefits. Especially green building design makes sure that the buildings are more efficient, productive and healthy due to enhanced indoor environments. Further, green building practices are perceived by many construction industry professionals to be part of the solution to problems regarding indoor environment of buildings. Even though, green buildings can be defined in various ways, giving correct definition to the term 'green' is supplementary problem compared to 'conventional' buildings. However, there is no doubt that the term has a very positive connotation. Further, green buildings generate lot of benefits to people and the environment. However, no evidence that level of occupant comfort and satisfaction are greater in 'green' rather than conventional buildings.

Hence, the purpose of this study was to identify the facts on differentiating green buildings from conventional buildings in terms of environmental performance. The GREENSL® rating system was used as the basis to evaluate environmental performance. The following section reviews the secondary data relating to the environmental performance in green buildings.

2. LITERATURE REVIEW

2.1. GREEN BUILDING

A study by Edward (1998 cited Karkanias *et al*., 2010) mentioned that the concept of green building has applied in most of the countries as to reduce the impact of buildings on environment and human health. According to a study by Kohler (1999), giving correct definition to the term 'green' is supplementary problem. However, there is no doubt that the term has a very positive connotation, but it is not quite clear why day lighting and acoustic protection should specifically refer to `green' buildings (Rees, 1992 cited Kohler, 1999).

The term 'green building' can be defined in various ways as mentioned in Table 1.

Table 1: Definitions of Green Buildings

Year	Source	Definitions
2000	Batuwangala	'a building, which is designed, built, operated, maintained or reused with objectives to protect occupant health, improve employee productivity, use wisely natural resources and reduce the environmental impact.'
2009	Edwin, Qian and Lam	'the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition.'
2012	Deuble and Dear	'green buildings (also referred to as green-intent buildings) by definition, aim to reduce their environmental impact by using less energy in both their construction and operation. Thus, buildings featuring natural ventilation capabilities are typically defined nowadays as green buildings.'
	Rashid, Spreckelmeyer, and Angrisano	'an any building with a Leadership in Energy and Environmental Design (LEED) certification from the USGBC is considered a green building.'
2013	Gou *et al.*	'as those featuring natural ventilation capabilities, i.e. low-energy or free-running buildings, are now at the forefront of building research and climate change mitigation scenarios.'

Through the various definitions, green building can be identified as a new building philosophy, encouraging the use of more environment friendly materials, and implementation of techniques to save resources and specially the improvement of indoor environmental quality, among others (Thormark, 2006 cited Lacouture *et al*., 2008). It offers an opportunity to create environmentally efficient buildings by using an integrated approach of design so that the negative impact of building on the environment and occupants' is reduced

(Ali *et al*., 2009 cited Hikmat *et al*., 2009). Henceforth, green building practices are perceived by many construction industry professionals to be part of the solution to problems regarding indoor environment of buildings (Hashim *et al*., 2011).

Green Certification

The success of green buildings depends on the quality and efficiency of the installed green systems. If the building lacks these essential features, it will neither accomplish the environmental goals nor generate the estimated benefits. Thus, the market requires a common way to differentiate green buildings from traditional buildings through the use of standard, transparent, objective, and verifiable measures of green, which assure that the minimum green requirements have been reached (Lacouture *et al*., 2008). Hence, a range of green building rating systems, protocols, guidelines and standards has been developed in the past 20 years that respond to the need to evaluate and benchmark levels of building achievement in the green revolution (Yudelson, 2008, 2010 cited Gou *et al*., 2013). Wallhagen (2010) further verified that the green assessment tools can also be used to produce guidelines, benchmarks, ratings and incentives to construct buildings with low environmental impact and to work as environmental management tools. Further, green rating tools establish common language and standards of measurement to define green buildings differentiating from traditional buildings (Yudelson, 2008, 2010 cited Gou *et al*., 2013).

The first of such tools was the Building Research Establishment Environmental Assessment Method (BREEAM) (Baldwin, 1998 cited Lacouture *et al*., 2008) and, the most representative and widely used green assessment tools are Leadership in Energy and Environmental Design (LEED), Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) and Green Star, Green Building Index (GBI) - Malaysia, Green Mark - Singapore, Hong Kong Building Environmental Assessment Method (HK-BEAM) and The Pearl Rating System for Estidama (Sustainability) (Roderick *et al*., n.d.; Boonstra and Pettersen, 2003; McKay, 2007). Similarly in Sri Lanka, there is a local rating system called GREENSL® introduced by the Green Building Council in Sri Lanka (GBCSL). The Green Building Council of Sri Lanka (GBCSL) came into existence as a result of an emerging trend towards applying the greener concepts for built environment (GBCSL, 2011).

2.2. ENVIRONMENTAL PERFORMANCE IN GREEN BUILDINGS

The success of the project depends on the implementation of environmental criteria (Lippaiova and Sebestyen, n.d.). As Lippaiova and Sebestyen further mentioned that the aim of green management is to satisfy the demands of users and the natural environment. Previous studies show that the environmental performance can be enhanced by moving to green from conventional buildings. According to a study by National Research Council Canada (2012), the strongest driver for the green building movement is the goal of reducing building energy use. As it further mentions another large credit category in green building rating systems is indoor environment quality (IEQ) in most of the green rating systems.

Further, the environmental conscious criteria are also the part of the quality criteria as the indoor environmental quality has positive effects on productivity and health (Lippaiova and Sebestyen, n.d.).Thus, green building certification schemes require building designers and managers to consider the impact of the indoor environment on the health and wellbeing of the office worker.

Table 2 shows that the level of consideration of few green building certification systems on indoor environment. Indoor environment is one of major criteria in many green certifications systems such as, LEED, and CASBEE, which is required to ensure by building designers and managers to obtain the green certification for buildings.

Table 2: Indoor Environment Quality Criteria in Green Assessment Tools

% of IEQ							
CRITERIA	**LEED**	**BREEAM**	**CASBEE**	**Green Star**	**GBI Tool**	**Green Mark**	**GREEN SL**
Management	04	16	05	09	39	-	04
IEQ	21	16	23	19	11	04	13
Energy	23	15	18	18	23	56	22
Transport	06	13	00	19			
Water	10	05	03	12	12	09	14
Materials	18	11	12	19	09		14
Land use	08	08	19	06	-	-	-
Environment protection	10	15	20	07	-	26	-
Innovation	-	-	-	-	06	-	04
Sustainable sites	-	-	-	-	-	-	25
Social and cultural awareness	-	-	-	-	-	-	04
Other features	-	-	-	-	-	05	-

Source: Boonstra and Pettersen (2003); Haapio (2008); Wallhagen (2010); InBuilt (2010); GBCSL (2011); BCA Green Mark (2013)

The superior indoor environments offered by green buildings will lead to more satisfied occupants with higher levels of well-being, and thus to better outcomes for the organisations that employ them. There is abundant evidence that better indoor environments do lead to such positive outcomes (Newsham *et al.*, 2008; Newsham *et al*, 2009b, Thayer *et al.*, 2010 cited NRCC, 2012).

Table 3: IEQ Parameters in Green Buildings

IEQ factor	**LEED**	**BREEAM**	**Green Star**	**CASBEE**	**GREENSL®**
Temperature and humidity	Controllability of systems	Local temperature control		Room temperature setting Variable loads and following-up control Zoned control Temperature and humidity control	Low - Emitting Materials Indoor Chemical and Pollutant Source Control
Acoustic	Controllability of systems	Noise	Internal noise levels	Background noise Equipment noise Sound insulation of openings Sound insulation of partition walls Sound absorption	Controllability of Systems
Ventilation	Environmental tobacco smoke control CO_2 monitoring Ventilation efficiency	Operable windows Air intake Fresh air	Ventilation rates	Ventilation rate Natural ventilation performance Consideration for outside air intake Air supply planning	Monitoring Increased Ventilation

IEQ factor	LEED	BREEAM	Green Star	CASBEE	GREENSL®
Indoor Air Quality	Indoor chemical and pollutant source control Minimum IAQ performance Construction IAQ management plan	Smoking Clean carpets	Air change effectiveness CO_2 and VOC monitoring and control Hazardous materials	Type of A/C CO_2 monitoring Control of smoking	Minimum IAQ Performance Smoke (ETS) Control Outdoor Air Delivery Construction IAQ Management Plan
Day Lighting and Lighting Quality	Low-emitting materials Day lighting	80% adequately day light Window antiglare Ballets Illuminance levels Independent lighting control	Daylight Daylight glare control High frequency ballets Electric lighting levels	Daylight factor Openings by orientation Daylight devices Glare from light fixtures Daylight control Illuminance level Uniformity ratio of illuminance Lighting controllability	Daylight and Views
Thermal Comfort	Thermal comfort	Thermal comfort	Thermal comfort	-	Thermal Comfort,
Access to Views	Views	Desks location	External views	-	Daylight and Views

Source: Boonstra and Pettersen (2003); Haapio (2008); Wallhagen (2010); GBCSL (2010)

As the above Table 3 presents that several measures relating to environmental performance can be identified. However, indoor air quality, acoustic quality, day lighting and lighting quality and thermal comfort were selected as main aspects to evaluate environmental performance in green and conventional building through preliminary investigation. The environmental performance evaluation framework was developed based on key literature findings as mentioned in following Figure 1.

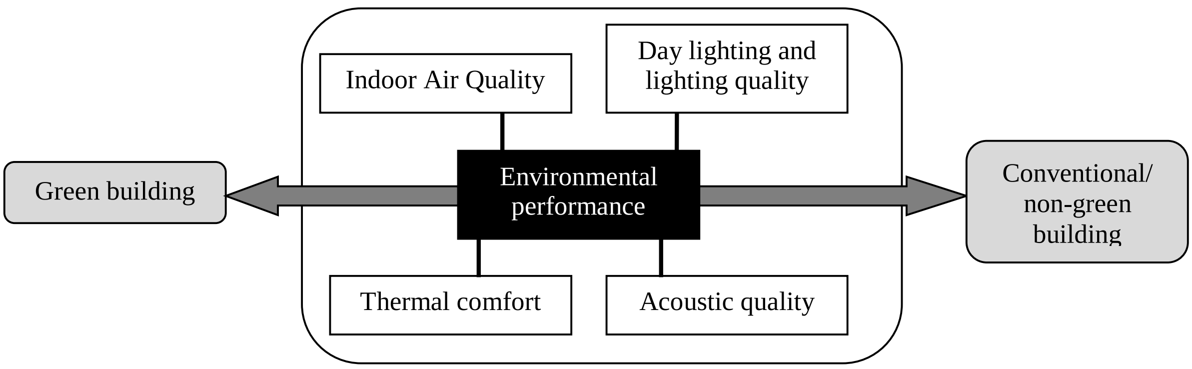

Figure 1: Environmental Performance Evaluation Framework

3. RESEARCH METHODOLOGY

The research was designed as two stages; literature survey (Stage - i) and preliminary investigation (Stage - ii). As the first stage, a comprehensive literature survey was conducted by referring key research papers in the areas of green buildings, IEQ parameters in several green building criteria and environmental performance factors. The environmental performance evaluation framework is developed based on key literature findings (refer Figure 2).

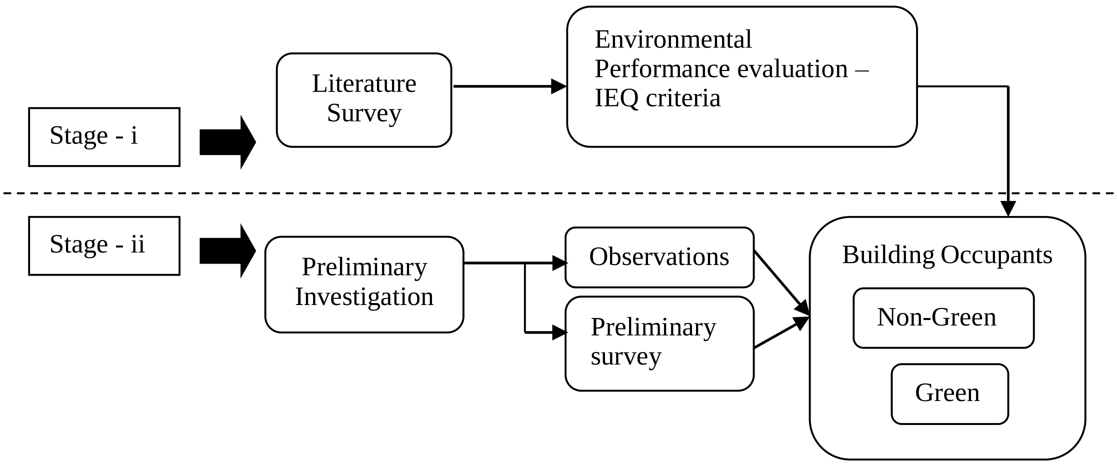

Figure 2: Stages of Research Design

The second stage of the research consists of a preliminary investigation thus; observations and preliminary survey were conducted with occupants in selected green and non-green buildings in Sri Lanka. Buildings to conducting preliminary investigation were selected based on green certification. Hence, the buildings with green certification were selected as green buildings, whilst buildings which have not obtained green certification were selected as non-green/conventional buildings. A sample of 30 occupants of green and non-green buildings was randomly selected and surveyed to collect the data. Observations and preliminary survey was done considering IEQ parameters in GREENSL® rating system as the evaluation criteria. It was used as the basis to evaluate and identify environmental performance features and major differences between green and non-green buildings.

The data collected through preliminary investigation were evaluated to identify environmental performance features in green buildings compared to conventional/non-green buildings. Following section 4 describes the analysis and findings of primary data collected through preliminary investigation.

4. RESEARCH FINDINGS AND DISCUSSION

As this research paper is based on preliminary investigation conducted at the beginning of this research study, this section is intended to present key research findings relating to the difference between green and non-green buildings in terms of the environmental performance.

As the researcher observed, the buildings with green certification had been implemented several IEQ measures as it is a major requirement to obtained credits for environmental performance. Hence, green buildings have been improved their indoor environments considering IEQ measures given in the local rating system. IAQ and ventilation, thermal comfort, day lighting and lighting quality and the acoustic quality factors were considered in data analysis to find major differences in between green and non-green building environments.

4.1. IAQ AND VENTILATION

According to the preliminary investigation, most of the occupants of green buildings had high satisfaction with air quality compared to non-green/conventional buildings. Most of them are preferred to work near operable windows with natural ventilation, as the building has been provided automatic air quality and polluter controlling features. Further, smoking areas which have been designed at the exterior is one of the other positive features in green buildings.

Compared to non-green buildings, green buildings facilitate high quality environment with quality indoor air as it gains maximum benefit from natural ventilation with the required controls on contaminants. Therefore, green buildings rated significantly higher satisfaction for IAQ and ventilation. This is due to the implementation of many strategies to enhance IAQ and to maximally use natural ventilation by facilitating comfortable environment to building occupants as mentioned in Figure 3.

IAQ and ventilation features in Green Buildings

- Exterior designated smoking areas
- Outdoor air intakes and operable windows
- Automatic air quality controllers
- Heat recovery
- Maximum use of natural ventilation
- Controlling pollutant sources, and interrupt pathways for contamination

Figure 3: IAQ Features in Green Buildings

4.2. THERMAL COMFORT

The green buildings have been designed consisting comfortable thermal environment by applying several strategies as mentioned in Figure 4. In addition, occupants of green buildings indicated that they were less likely to prefer a change in thermal conditions. However, individual controllers had been made them more comfortable within the working environment in green buildings.

Thermal quality features in Green Buildings

- Individual thermostat controls
- Local diffusers at floor, desk or overhead levels
- Thermal comfort systems
- Continuous monitoring and maintenance of the thermal environment
- Maintain thermal quality standards

Figure 4: Thermal Quality Features in Green Buildings

Further, compared to conventional work setting, green buildings have designed with monitoring and controlling systems to maintain thermal quality standards. Most of the occupants stated that they have not felt uncomfortable in thermal environment while they are working. Thus, the data collected through preliminary investigation shows that compared to conventional/non-green buildings; there are highly satisfied occupants with thermal comfort in green buildings.

4.3. DAY LIGHTING AND LIGHTING QUALITY

Even though green buildings have been implemented several strategies to enhance the lighting quality and visual comfort, the investigation did not show a big difference or considerable improvement in green buildings compared to non-green buildings. However, occupants were satisfied with their access to view of outside environment in green buildings rather in conventional buildings.

It is because that the green buildings have lighting conditions closer to recommended practice, and provide more access to daylight, than conventional buildings. Further, green buildings have designed with following day lighting strategies (refer Figure 5) to make occupants more comfortable in their working environment compared to non-green buildings.

Day lighting /lighting quality features in Green Buildings

- Individual lighting controls
- Maximize day-lighting and view opportunities
- Building orientation,
- Shallow floor plates
- Increased building perimeter
- Exterior and interior shading devices
- High performance glazing, and photo-integrated light sensors

Figure 5: Day Lighting and Lighting Quality Features in Green Buildings

4.4. ACOUSTIC QUALITY

According to the preliminary investigation, one design feature of the IEQ that continuous to be a problem is acoustic. Even though green buildings had high satisfaction in terms of IAQ and thermal comfort compared to conventional buildings, it showed considerable decrease in satisfaction of acoustic comfort in green buildings. As the design features of green buildings have been considered the maximum use of natural ventilation and day lighting with the access to view outside environment to facilitate comfortable environment to building occupants, it has created high background noise levels in green buildings than conventional buildings. Most of the occupants said that they are always feeling uncomfortable with background noises generated. Thus, most of them feel uncomfortable to work near operable windows. In addition, the use of glass in the building enclosure is also driven to make acoustically uncomfortable indoor environment as it lead to decrease sound isolation between interior spaces even though interior glass partitions help to transmit day light into building.

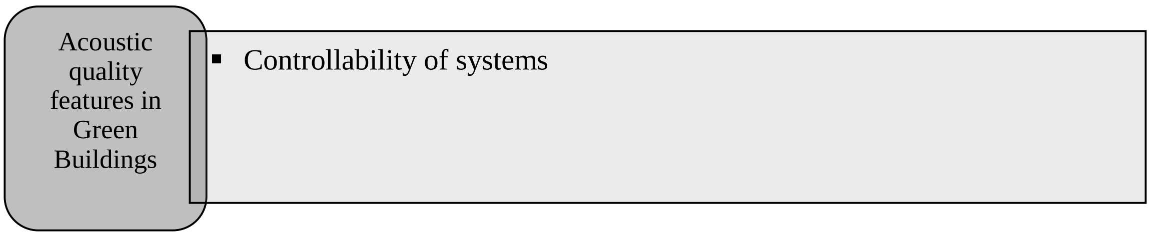

Figure 6: Day Lighting and Lighting Quality Features in Green Buildings

However, no additional features have been introduced in green buildings to ensure acoustic quality within the building environment. The only strategy introduced by the local rating system is making provisions to ensure controllability of systems within the building premises (refer Figure 6). Green buildings are required to implementing additional strategies to reduce acoustic quality issues beard by the occupants.

When considering the environmental performance in green and conventional buildings, there are several similarities and differences can be identified in terms of IAQ, thermal comfort, acoustic quality and the visual comfort. Green buildings shows highly positive response towards thermal comfort and IAQ compared to conventional buildings. Hence, in green buildings, satisfaction with thermal comfort and IAQ has been increased greatly. Lighting quality also should be further considered whilst the satisfaction of occupants on acoustic quality declined considerably. Further, the overall scoring of building occupants for environmental performance is much higher in green buildings compared to conventional buildings.

5. SUMMARY

As the major purpose, this study was aimed to evaluate green and non-green built environments in order to differentiate such two building categories in terms of environmental performance features. As the results of preliminary investigation, occupants of green buildings were more satisfied with IAQ and thermal comfort compared to conventional buildings. Further, there is no big difference has been shown in occupants' satisfaction on lighting quality in both green and conventional buildings. Green occupants had been more satisfied to work connected with outside environment. However, the satisfaction on acoustic quality in green buildings declined slightly with high background noise due to maximum use of open areas and glass interiors. Thus, careful and coordinated design as well as good acoustic strategies should be implemented throughout the design process by introducing them through local green rating systems. The credit allocation for acoustic quality aspect in GREENSL® can be increased out of 13 IEQ credits. By considering the research findings, green buildings show high environmental performance differentiating from conventional buildings. However, it was rare for all green buildings to perform better environmental performance than their conventional buildings. It is because that the success of green buildings depends on the quality and efficiency of the installed green systems. Therefore, the rating system can be used as the common language and standards of measurement to define green buildings differentiating from conventional buildings.

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EFFECTS OF VARYING RECYCLED FINE AGGREGATE CONTENT AND WATER/CEMENT RATIO IN BEDDING MORTAR

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ABSTRACT

This paper presents the results from a research carried out with the aim of analysing the usability of Recycled Fine Aggregates (RFA) produced from Construction and Demolition Waste (CDW), in bedding mortar. Properties of RFA were compared to that of the Natural Fine Aggregates (NFA) in terms of Bulk Density, Fine Fraction, Particle Size Distribution, Water Absorption and Chloride Content and were tested for five mixed proportion scenarios of RFA and NFA at 0%, 25%, 50%, 75% and 100% RFA contents. RFA indicated a water absorption of 6.33% when compared to that of 0.71% for NFA (ordinary river sand). Mortar testing was further divided under three water/cement ratios at 0.5, 0.6 and 0.7. Bulk density gradually decreased with increased RFA content yet recorded an exceptional highest of 1476Kg/m^3 at 75%RFA. Results from fine fraction and particle size distribution indicated compatibility of RFA to replace NFA up to 50% RFA. Chloride content analysis indicated allowable RFA replacement levels up to 99% and 44% for bedding mortar and plastering mortar applications, respectively. Though higher water absorption demanded for higher water content, Compressive Strength increased with the increasing RFA content, even above NFA values, reaching a maximum of 15.2 ± 0.50 N/mm^2 at 75% RFA for 0.7 water/cement ratio while workability was within the acceptable range at 50% RFA at the same water content. The analysis in terms of fine aggregate properties and mortar properties showed that up to 50%, NFA can be substituted with RFA at water/cement ratio of 0.7 in bedding mortar which will also attribute to a cost reduction of minimum 50%, as well as to greatly reduce the disastrous environmental impacts from sand mining and waste disposal thus enhancing sustainability.

Keywords: *Compressive Strength; Construction and Demolition Waste (CDW); Workability.*

1. INTRODUCTION

With the significant technological development currently experienced worldwide, the rate of pollution and waste emission has increased significantly. Though municipal and industrial waste plays the major roles as waste streams, demolished construction waste has also being added to that list as another major stream of waste which is becoming important day by day due to the increase of construction activities. With the concept of recycling in rise, the focus has shifted to the use of recycled construction and demolished waste as an alternative for fine and coarse aggregates in the construction industry. In addition, rising demand for construction materials, increases depletion of raw materials such as sand and aggregates plus the environmental damage from material production has led to the popularity of this concept (COWAM, 2009).

Even though there are certain alternative fine aggregates like sea sand, quarry dust and dredged sand from silted reservoirs which have already been used in Sri Lanka, there are certain issues associated with each of these alternatives which have led to adverse effects. Corrosion issues associated with the excess salt and chloride content in sea sand and coastal erosion as a result of the sea sand dredging activities have made the use of this alternative problematic. Sand dredged from silted reservoirs and use of quarry dust have also failed to come into industrial use due to issues related to environmental effects as well as scarcity of these resources. This research focuses on the use of recycled aggregates which mainly formed from the waste generated from demolition of constructed structures, as an alternative for fine aggregates in bedding mortar. Demolition of a certain structure may occur due to reasons like, exceeding of the useful lifetime, demand for more sophisticated and space saving building designs or even due to natural disasters like tsunami or earthquakes (Shelter-Center, 2011).

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The major focus of this research is to study the suitability of the recycled fine aggregates to be used in bedding mortar and raise awareness for wider systematic use of recycled Construction and Demolition Waste in Sri Lanka as a construction material. Aspects to be considered when using recycled fine aggregates for construction purposes and to identify the limitations in recycled aggregate mortar preparation with respect to water/cement ratio, finer percentage and other important properties are studied under this research.

2. LITERATURE REVIEW

When analysing recent history, the use of recycled aggregates seems to be a very common practice all around the world, though it seems an unfamiliar territory in the Sri Lankan context. Instances for the use of Recycled Aggregates from CDW can be found mostly in developed countries like UK, Japan and Germany, where they have been used to construct building materials and paving bricks in the forms of mortar and concrete (Vyncke, 2001).

Particle size distribution, fine fraction, specific gravity, water absorption, bulk density and chloride content are some of the important aggregate properties that had been analysed to determine the suitability of fine aggregates for construction purposes. In terms of important mortar properties, workability and compressive strength characteristics of mortar have been analysed in previous researches (Thurston, 2011).

3. MATERIALS AND METHODS

3.1. PREPARATION OF SAMPLES

A bulk sample of RFA produced from demolished building waste was collected from the Construction Waste Management (COWAM) centre site in Galle and was used as the materials for testing.

3.2. TESTING OF FINE AGGREGATES

Followings tests were carried out to test the fine aggregate properties of recycled fine aggregates and natural fine aggregates while tests were done for five mixed proportion scenarios (RFA and NFA) at 0%, 25%, 50%, 75% and 100% RFA contents.

- Sieve Analysis Test - (ASTM C 144-84)
- Specific Gravity and Water Absorption Test - (BS 812-Part 2:1995)
- Bulk Density Test - (ASTM C 29-09)
- Fine Fraction - (ASTM C117-95)
- Chloride Content - (BS 1377-Part 3:1990)

3.3. TESTING OF MORTAR

To evaluate the properties of mortar made using RFA, the RFA were mixed with NFA under five different scenarios similar to the aggregate testing and were further tested under three water/cement ratios as indicated in Table 1.

Table 1: Mix Proportions Used for Mortar Testing

Scenario No.	% of Recycled Aggregates	% of Natural Aggregates	Water/cement Ratio
1	0	100	0.5 0.6 0.7
2	25	75	0.5 0.6 0.7
3	50	50	0.5 0.6 0.7
4	75	25	0.5 0.6 0.7
5	100	0	0.5 0.6 0.7

Following tests were done to determine the mortar properties.

- Workability of fresh mortar - (BS EN 1015-3)
- Compressive strength of test cubes - (BS 1377-part 2 : 1990)

The workability of each and every mix was tested prior to the making of mortar specimens. With regard to compressive strength testing, curing was carried out as per the BS standards after the preparation of the mortar specimens. The testing of those specimens was done for 7 days, 14 days and 28 days.

4. RESULTS AND DISCUSSION

Mortar is a mixture of fine aggregates, water and cement. Initially the properties of the RFA were compared to those of NFA in five mix proportions to analyse the effects of varying RFA content on aggregate properties.

4.1. AGGREGATE TESTS

When the particle size distribution results given in Figure 1, are considered the gradation curves for all five mixtures are mostly within the standard envelope accepted for fine aggregates to be used in bedding mortar applications.

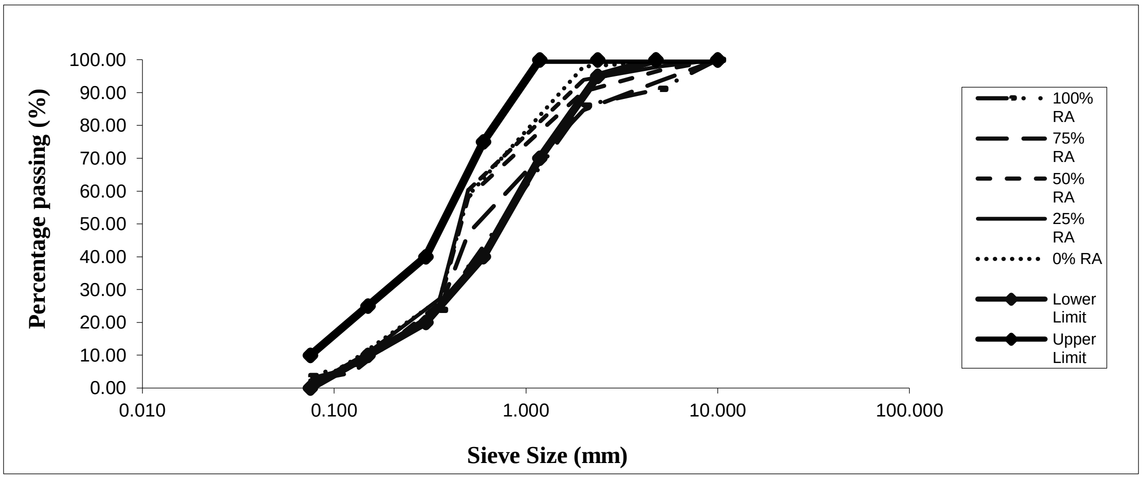

Figure 1: Percentage Passing (%) vs. Sieve Size (mm)

Further analysis with regard to fine fraction test indicates an inversely proportional relationship between the fine fraction and the decreasing RFA content. It reveals that RFA has higher amount of fine particles reaching a maximum of 13.47% at 100% RFA and being lowest at 1.51% for 0% RFA (i.e.100% NFA). The statistical analysis gives P values well within the acceptable range of difference, making the results highly reliable.

Though according to standards, the fine content of 13.47% in RFA is within the acceptable limit of 30% for fine aggregates produced from crushed rock, it is expected to adversely affect properties of bedding mortar.

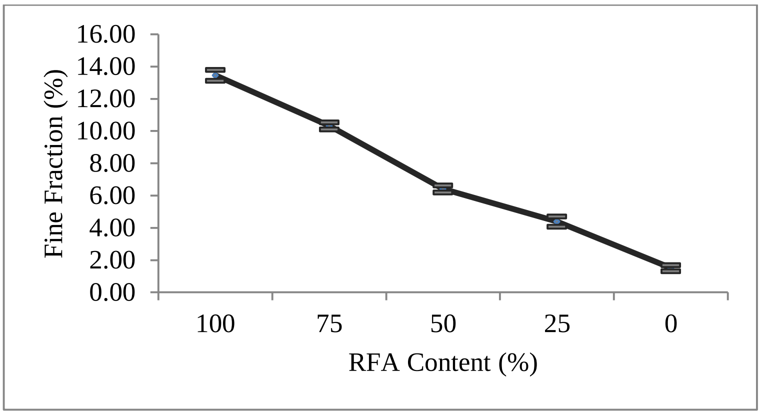

Figure 2: Fine Fraction (%) vs. RFA Content (%)

When considering the different parameters of fine aggregates bulk density is also another important parameter which differentiates the RFA from NFA. When considering the bulk density values for each mix proportion given in Figure 3, the P value (T-test) is less than 0.0001. By conventional criteria, this difference is considered to be extremely statistically significant.

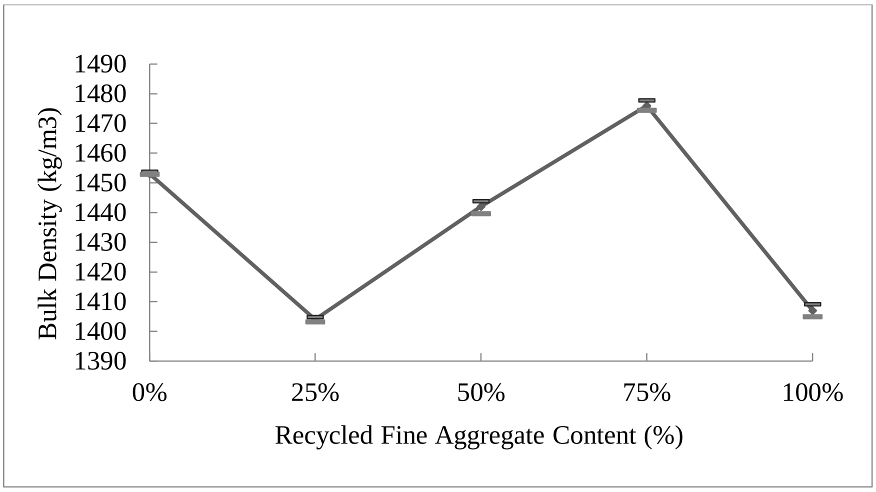

Figure 3: Bulk Density (kg/m^3) vs. RFA Content (%)

Generally the tendency indicated is for the bulk density to decrease with the RFA content due to the increase in microspores resulting in values of 1453kg/m^3 and 1407kg/m^3 at 0% and 100% RFA respectively. Packing ratio of the particles which is one other factor which governs bulk density can be used to explain the maximum bulk density value of 1476kg/m^3 being recorded at 75% RFA content.

Water absorption is a vital characteristic of fine aggregates important in determining the water/cement ratio of the mortar mix. In this case, RFA shows relatively a higher water absorption of 6.33% compared to the normal values of 0.71% for NFA. This high water absorption can be traced back to the high fine content in RFA. The P value (T test) of Water Absorption of NFA and 100% RFA equals 1.03876x10^{-6} By conventional criteria, this value is considered to be within acceptable range, so the data are highly independent.

Table 2: Water Absorption (%) of RFA and NFA

Sample Type	NFA	RFA
Water Absorption (%)	0.71	6.33

Chloride content is basically an important aspect to consider especially when aggregates are utilised for constructions with embedded metallic components. Annexure D of BS EN 13139 recommends that the water soluble chloride content of the fine aggregates should not exceed 0.15% for bedding mortar and the limitation further narrows down to below 0.06% for mortar with embedded metallic appliances.

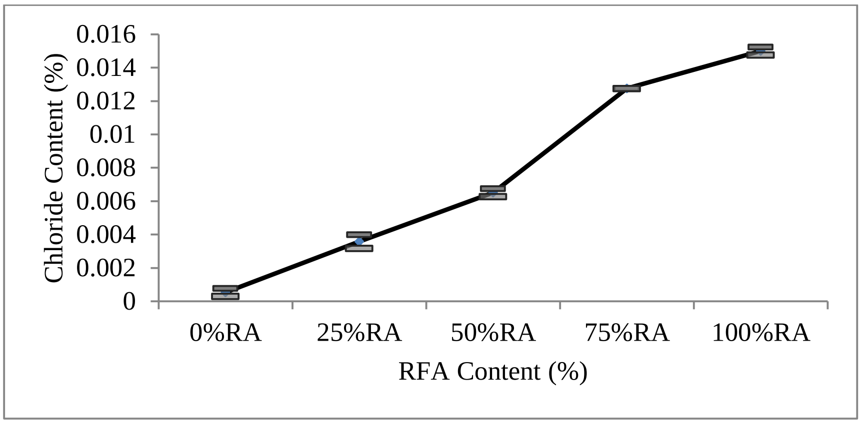

Figure 4: Chloride Content (%) vs. RFA Content (%)

When we consider the standard deviation and the P values for this data set it gives a value as low as 3.48 x 10-14, which is by conventional criteria can be considered to be not statistically significant difference, so the results are highly accurate.

When considering the basic applications for bedding purposes mixtures of up to 99% RFA content can be used within permissible chloride content. But when considering applications where mortar is used with embedded metals, aggregate mixtures up to 44% RFA can be used.

4.2. MORTAR TESTS

Proceeding to mortar testing, the mortar mixtures were made in accordance with the five mix proportions and further tested for three water/cement ratios of 0.5, 0.6 and 0.7 to analyse the effect of varying water content on properties bedding mortar made with RFA.

Initially the testing was carried out to determine workability which defines the convenience provided to mason when using the mortar for masonry applications. Mortars with high flow values or low flow values would cause inconvenience and would result in time consumption as well as structural failure. BS EN 1015-3 standard provides that flow values obtained for fresh mortars should be within 100-115% range for optimum workability.

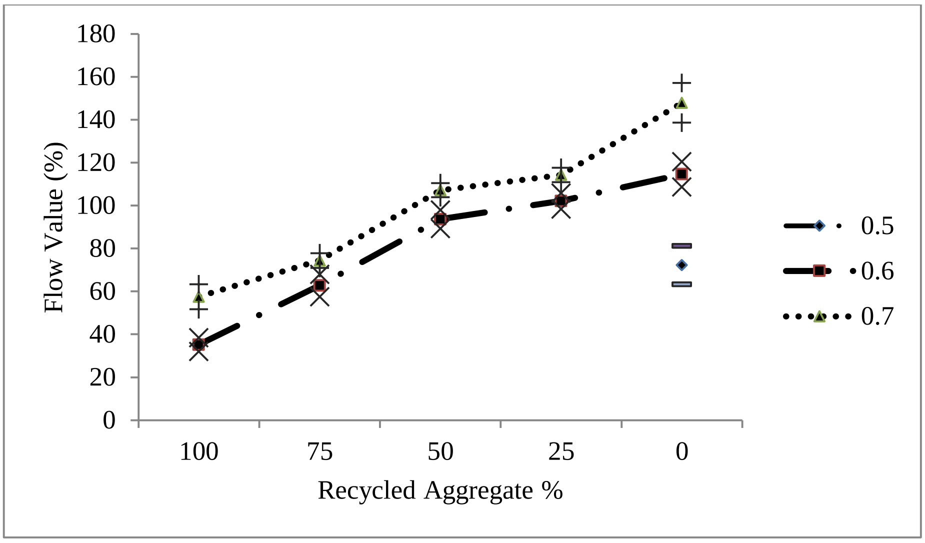

Figure 5: Flow Value (%) vs. RFA Content (%)

The statistical analysis of the 0.6 and 0.7 water cement ratios in the flow table test results in Figure 5 gives P values of 7 x 10^{-9} and 2 x 10^{-8} respectively which are well within the acceptable range of difference, making the results highly reliable. Water/cement ratio 0.5, indicated to be insufficient to provide acceptable flow values for any of the five mix proportions.

When 0.6 water/cement ratio is used, 100%, 75% and 50% RFA mixtures had low flow values. But the 25% and 0% RFA mixtures had acceptable flow values within 100% - 115% range. When the water/cement ratio was increased to 0.7 acceptable flow values were obtained for the 50% RFA and 25%. It is such that the increasing water content seems to increase the flow of mortar and when it passes the optimum level at 55 RFA% the RFA amount won't be enough to absorb the water content and the excess water would make it undesirable due to high flowing characteristics.

Compressive strength results in terms of 28 days strength given in Figure 6 can be considered as the most important characteristic in terms of strength and durability of hardened mortar. With time it is evident that all the compressive strength values had exceeded their respective 14 day and 7 day values indicated in Figures 7 and 8, respectively. When statically analysing of the graphs in Figure 6, the respective P values for 0.5, 0.6 and 0.7 water/cement ratio graphs are at 0.00026, 0.005 and 0.00029 meaning that they are within the conventionally allowable insignificant difference limits, making the results of these graphs more reliable.

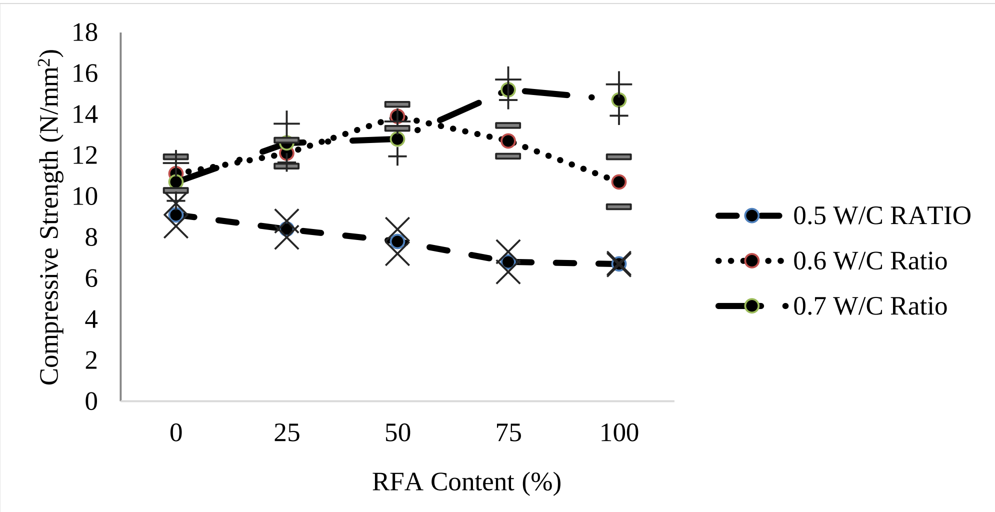

Figure 6: 28 Days Compressive Strength

With reference to the 0.5 water/cement ratio the compressive strength of the mortar cubes shows a declining trend, continuously from 0% to 100% RFA mixture. Lack of water required for bonding may have resulted in this phenomenon. With the high water absorbing characteristics of RFA, it is clear that when the RFA% is increased at 0.5 ratio the lack of water for bonding issue increases, resulting in a relatively steady decline in the compressive strength of mortar.

When the 0.6 water/cement ratio is considered, the trend seems to be an increase in compressive strength up to about 50% RFA content and then a declination. The initial increase in strength can be explained as due to the excess amount of water at 0.6 water/cement ratio which continues to be absorbed up to an optimum level when the RFA% is increased. But from the 50% RFA onwards, once again there seems to be a lack of water in mortar for bonding which decreases its compressive strength similar to the 0.5 ratio scenario.

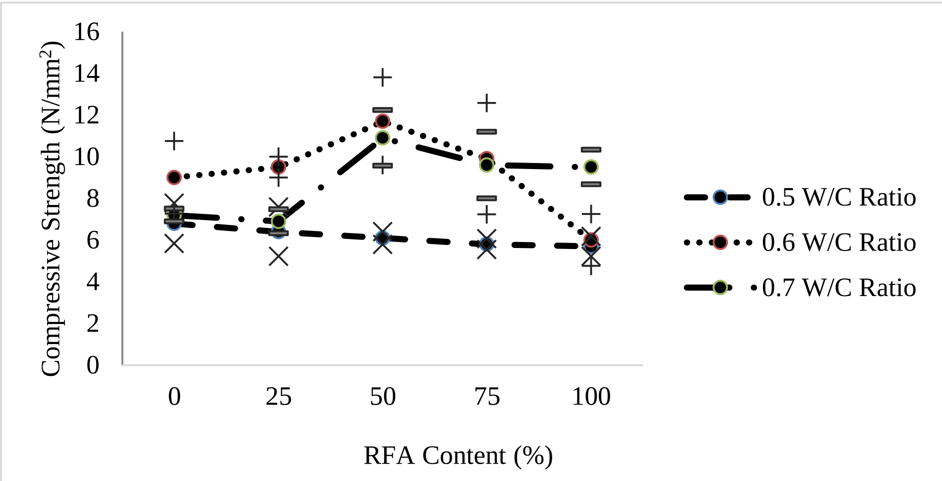

Figure 7: 14 Days Compressive Strength

Analysis of the 0.7 water/cement ratio data indicates a similar pattern by increasing in strength up to 75% RFA mixture and then on showing a dip. This may once again be due to the excess water the mortars up to 75% RFA contained and then on the lack of water due to the high water absorbance by the RFA.

The data variance and P values are relatively higher for the 14 day and 7 day results making the results less reliable. After analysing the 28 day results it is visible that the 14 day results also gives traces for a similar outcome as shown in in Figure 7.

When considering the 7 day compressive strength results in Figure 8, the values are randomly distributed making it evident that more time is required for the mortar bonds to settle into a steady state.

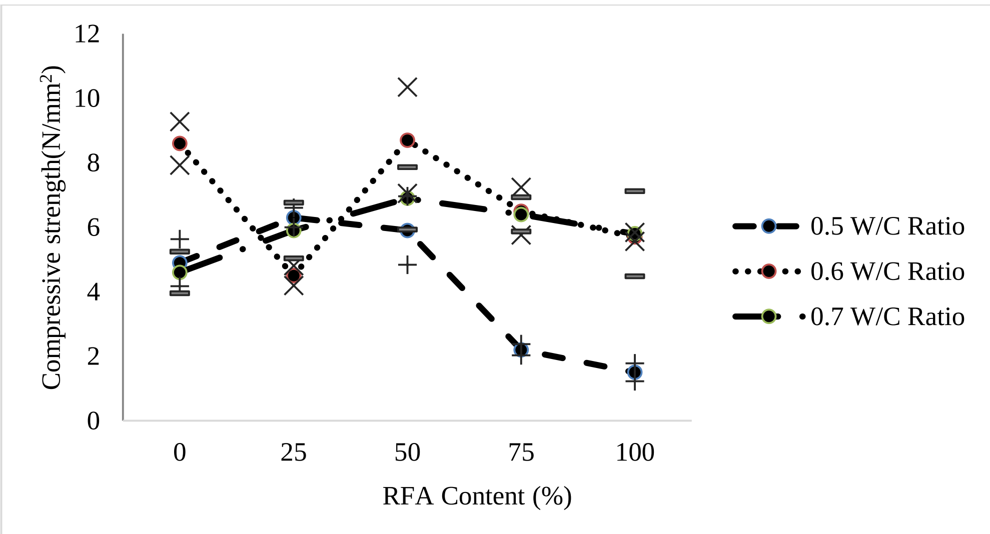

Figure 8: 7 Days Compressive Strength

5. CONCLUSIONS

Aggregate properties of RFA such as Bulk Density, Water Absorption, Fine Content and Chloride Content showed a relatively inferior yet acceptable quality when compared to that of NFA, mainly as a result of the higher fine content. Use of a washing process can be recommended to improve the quality of RFA. However, at water/cement ratios as high as 0.7 to compensate for the high water absorption, mortar made out of RFA showed lesser impacts on the compressive strength and workability when compared to that made from 100% NFA. The compressive strength values reached a maximum of 15.2 ± 0.50 N/mm^2 at 75% RFA for 0.7 water/cement ratio while workability was within the acceptable range at 50% RFA at the same water content. Under higher water/cement ratios of about 0.7, the compressive strength values shows a tendency to increase with the increase in RFA content, even above compressive strength values of NFA mortars.

Mortar made by using mixture of 50% RFA with 50% NFA, at water/cement ratio of 0.7, indicates to be most suitable for construction purposes since it has achieved the optimum workability as well as acceptable and higher strength values than 100% NFA leading to a 50% cost reduction as well as environmental sustainability.

6. ACKNOWLEDGEMENT

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ENHANCING THE VALUE IN CONSTRUCTION VIA INTEGRATION OF SUSTAINABLE CONSTRUCTION TO VALUE PLANNING

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ABSTRACT

Sustainable Concept (SC) has shed a spotlight towards the rapidly developing construction sector since concerns on SC principles are widely emerged recently which focused to ensure both present and future generations a good quality of life. Currently Sri Lanka is on construction boom which feeds the requirement of establishing sustainable concept to the construction projects. This paper aims to investigate the current situation of Value Planning (VP) and SC in local construction sector and to present a framework for integrating concept of value for money in sustainable construction.

A comprehensive literature survey was carried to observe the existing knowledge on SC and VP concepts to develop a conceptual linkage between the two disciplines. This was followed by an expert semi structured interview survey among experts having considerable knowledge on both aspects to ascertain the current situation of those concepts in Sri Lankan construction industry. Findings of the research revealed that the application, knowledge and experience of experts are not satisfactory in both of these concepts. It is established that there is a huge requirement of applying these concepts in local construction projects. In order to overcome the issues identified, a Framework has been developed to integrate SC and VP in Sri Lankan construction projects.

Keywords: *Infrastructure Projects; Sri Lanka; Sustainable Construction; Value.*

1. INTRODUCTION

The construction industry has both positive and negative impacts on environment as well as people. The effect of impact will vary accordingly with rise or fall of the industry. In Sri Lankan context, construction industry became a major contributor with average 7% contribution to the Gross Domestic Production (GDP) and by showing a 17.3% growth in Sri Lankan economy which is a record in 2009 (Central Bank Annual Report, 2009). In addition the sector provides job opportunities for about 7.2 % of the country's total work force which amounts to around 570,000 persons (Media Centre for National Development Sri Lanka, 2012) while the industry's contribution to Gross Domestic Capital Formation was 70% (Rajapaksha, 2010). These evidence shows that Sri Lanka is currently experiencing a construction boom due to the increased interest of investors after end of the three decade-long conflict and restoring the peace. This boom is being encouraged by rapidly expanding tourism sector as well as major government infrastructure projects. As a negative effect, however, this will lead to increase in adverse environment issues since rise in construction industry conversely depleting natural resources which causes unwanted side effects while the impact caused by construction activities on the environment occurs throughout the project life cycle (Athapaththu, 2012). It is estimated that the construction industry is responsible for approximately 40% of energy consumption, 30% of CO_2 emissions and 40% of total solid production waste globally (Hajek, 2002).

If the construction industry is to provide the required buildings, infrastructure and reduce environmental degradation, it must adopt more sustainable practice and policies (Ngowi, 2000). The objectives of SC include environmental impact reduction, resources optimisation, social and cultural improvement, achievement of quality, affordability and durability in a project (Kibert, 2008). Although the sustainable concept is a vital requirement to the world and for safeguard of future generations, there are several potential barriers to the implementation. The key barrier is perceived as cost since the common perception about sustainable buildings appears to be that they cost more than ordinary buildings (Castillo and Chung, 2005). Furthermore Castillo and Chung stated that sustainable buildings increase initial costs by an average of 2 to 7 percent over ordinary building cost. According to Bartlett and Howard (2000), engaging sustainability

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issues in construction projects faces several challenges such as negative perception about cost. This shows that clients may tend to dislike the SC approach because of this cost factor. Conversely, Value Management (VM) attracts clients since it reduces the unnecessary costs of the project with no deduction to the expected quality and performance (Hayles *et al.*, 2011).

Value Management is about how to create the best value of products or services on the basis that the function must be sustained (Fong *et al.*, 2001). As a systematic, multi-disciplinary and structured methodology, Value Management aims to improve the value and optimise the life cycle cost of a facility through identifying opportunities to remove unnecessary costs while ensuring quality, reliability, performance, and other critical factors to meet or exceed the customer's expectations (International Federation of Accountants, 2012). More deeply, there are economic considerations of SCs as profitability, lifecycle cost, rehabilitating cost of ecosystem, resettling cost of people, adverse impact on tourism value and employment of labour (Athapaththu, 2012). Accordingly it is clearly identifiable that the value for client's money is not directly addressed in the SC concept as well as cost which have to incur is more than the VM. In this context, Sustainable approach can be introduced through value management as an integrated approach to the clients which will be more effective rather than applying SC alone. The expected benefits will not be one ended since the client will have a better value for his money while the other stakeholders will be beneficial environmentally, economically and socially through their sustainability.

Thus, this paper aims at present a framework to integrate SC to VP in construction projects. The scope of this paper covered a brief introduction to SC, VP and their viable linkages, the current status of integration of VP in SC in Sri Lanka and a framework for integration.

2. LITERATURE REVIEW

2.1. SUSTAINABLE CONSTRUCTION

According to the United Nations World Commission on Environment and Development (WCED) sustainable development is defined as 'development that meets the needs of the present generations without compromising the ability of the future generations to meet their own needs (2012). The construction industry concentrates on the three aspects of sustainability; environmental, social and economic, in different ways.

Ministry of Environment and Natural Resources (MENR) in Sri Lanka has identified the timely requirement of sustainable development as they put a step forward to contribute sustainable development in Sri Lankan context by introducing a guideline which is named as National Sustainable Development Strategies (NSDS). The Green Building Council was established in 2010 in line with Tsunami Sustainable Building Guideline for South-East Asia which provides numerous environmental, safety and financial benefits through sustainable reconstruction management guideline (UNEP, 2007). There are some few building projects which were recognised in the Sri Lankan construction industry as sustainable buildings such as Heritance Kandalama hotel and MAS Intimates Thurulie (Pvt.) Ltd. Even though some steps were taken to introduce and deliver sustainability to Sri Lankan construction industry, still Sri Lanka is struggling from not only environmentally but also economic and social issues due to unstable development during past decades (Athapaththu, 2012). Thus, Employers, Clients, Contractors, Consultants, Government and all other stakeholders of the industry have great responsibility to work towards efficient design, construction and maintenance of our built environment in sustainable manner through the inevitable adoption of sustainable practices.

2.2. VALUE PLANNING

Value Management (VM) is a systematic approach that analyses the facilities, services, supplies, functions of systems and equipment to ensure they achieve their essential functions at the lowest life-cycle cost consistent with required performance, quality, reliability and safety. Typically the implementation of the VM process increases performance, quality, reliability, durability, effectiveness, safety or other desirable characteristics (Kelly Male and Graham, 2004). The systematic process of value management can be simply divided into three main phases, namely Value Planning, Value Engineering (VE) and Value Analysis (VA) to ensure that the value is delivered to the project in the most effective manner.

VP is applied in the earliest stages of a project prior to the decision to build the project or at the concept phase of a project (Kelly, Male and Graham, 2004; Ashworth and Hogg, 2000). Significant reason for application of VP in the concept phase of a project is to ensure that value is planned into the whole project from its inception.

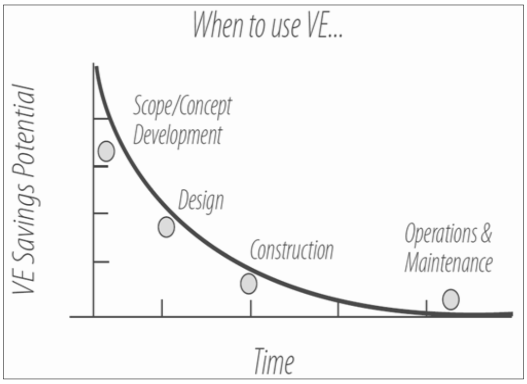

Figure 1: When to Use Value Engineering

Figure 1 shows that application of VE at the earliest stage has the highest saving potential with delivering the maximum value for a project. Accordingly the selection of VP is justifiable and more benefits can be achieved through integration of SC at earlier stages.

General concern of the local construction industry is to reduce the cost rather than improving the actual value of the outcome (Gamage, 2011). This is due to Sri Lanka is still a third world country and the majority of local citizens need the end product just only to fit to the purpose. However currently there is an increment of the value consideration in Sri Lankan construction industry (Rajapaksha, 2010).

2.3. Conceptual Link between Sustainable Construction and Value Planning

It has been understood that VM and SC have strong linkages and relationships in terms of their application and aims in construction projects.

Kelly *et al*. (2004) identified strengths and limitations of value management which can be similarly used as strengths of VP to integrate SCs. These are as involvement of multidisciplinary professional teams, different skills and techniques to build knowledge of SC, structured and systematic job plan to deliver SC, creativity phase generates sustainable options and avoid initial idea that springs to mind, function analysis can be used to identify and understand the project and use sustainable dimensions as project functions, the VM tools and techniques help decision-makers to take correct and suitable actions, the critical timing of VM provides significant positive effects on whole project delivery, VM is applied in a successive manner which enhances and monitors SC process, VM can be used as quality assurance to monitor sustainable principles, VM proposals are based on cost-effectiveness and considered sustainability dimensions could be used to persuade clients' attitude in future, potential to reduce the project whole life-cycle cost, even if it contains sustainable principles, through eliminating unnecessary cost; and facilitator helps to guide the process. Furthermore Kelly *et al.* (2004) demonstrates some limitations as time restriction, client commitment is a necessary to promote SC, and it needs the team members to have knowledge on both topics, VM and SC.

3. Research Methodology

Comprehensive literature review has been carried out in order to observe existing literature on sustainable concept and value planning concept individually and the extent to which those has been addressed on the scope of integration in local context and international context. Identification of the conceptual linkage was done accordingly to feed the main conceptual framework derived from VM job plan.

Data required for the research were collected using Expert Semi-structured interviews which are the most appropriate method for collecting qualitative information. An appropriate interview guideline was prepared by focusing on the main two topics in terms of application, current status and barriers to implementation including both closed ended and open ended questions. Selected sampling method was non random sampling which also known as purposely sampling technique since this research is specific to VP and SC which are not generic in the Sri Lankan context. This was used as a filtering process of the required experts from the general expert population. Accordingly the data was obtained by conducting interviews with 16 experts having significant experience in Sri Lankan construction sector projects with both Sustainable and Value planning concepts applied. The interviewee profile is presented in Table 1. Some interviews were audio recorded as with the permission of the interviewers. Transcripts were prepared with the help of those recordings in order to use in the analysis process. Since the Collected data of this consists with both closed ended (Quantitative) and open ended (Qualitative) portions, data analysis was also required to use statistical analysis and content analysis separately.

Table 1: Interviewee Profile

Number	Profession	Experience Category
1	Quantity Surveyor	More than 20 years
2	Quantity Surveyor	15 – 20 years
3	Quantity Surveyor	15 – 20 years
4	Quantity Surveyor	10 – 15 years
5	Quantity Surveyor	10 – 15 years
6	Quantity Surveyor	05 – 10 years
7	Engineer	15 – 20 years
8	Engineer	10 – 15 years
9	Engineer	10 – 15 years
10	Engineer	10 – 15 years
11	Engineer	05 – 10 years
12	Architect	More than 20 years
13	Architect	10 – 15 years
14	Architect	05 – 10 years
15	Project Manager	More than 20 years
16	Project Manager	15 – 20 years

The analysed research findings are presented below in separate sections.

4. FINDINGS

4.1. OVERVIEW OF SC AND VP

This section focused on qualitative data findings which are analysed using standard SPSS software (Statistical Package for the Social Sciences). Five closed ended questions were asked from respondents regarding both SCs and VP with each having a respondent scale of five answers. The analysis was done to get an overview on level of application, importance, and satisfaction on current status, current knowledge and required application level, stage of application and the team leader of both SC and VP.

4.1.1. *FREQUENCY OF APPLICATION*

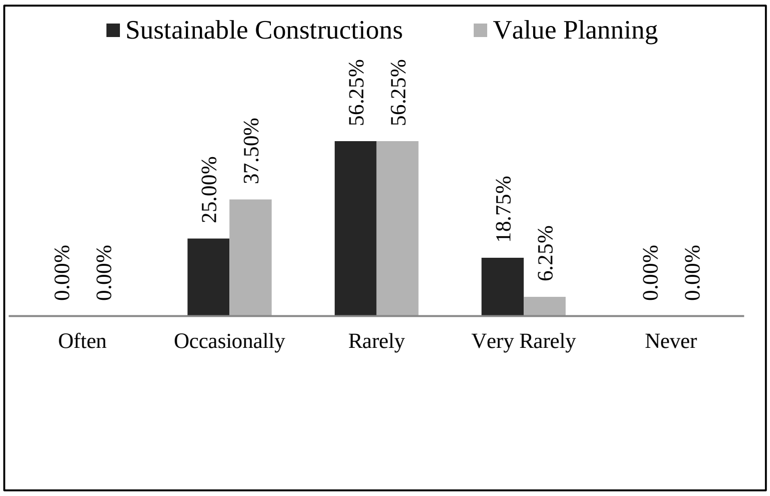

Figure 2: Frequency of Application of SC and VP

Application level of VP is slightly higher than the application level of SC in Sri Lankan construction sector. However the overall consideration impressed that the current application level is rare in both these disciplines as shown in Figure 2. The reasons were identified mainly as lack of awareness of people, clients dislike and shortage of experts.

4.1.2. *LEVEL OF IMPORTANCE*

According to the Figure 3 it is crystal clear that ultimately 100% of the expert sample established that the levels of importance in both these concepts are high or very high.

The reasons were that currently Sri Lanka is on construction boom with vast building and infrastructure developments. Therefore, sustainability is a vital requirement globally as well as locally since resources are getting low rapidly. Thus, social, environmental, and economical sustainability is emerging as a vital requirement. Moreover, Value for money is becoming essential to the clients since the scope, complexity, size, and cost of construction projects are increasing rapidly.

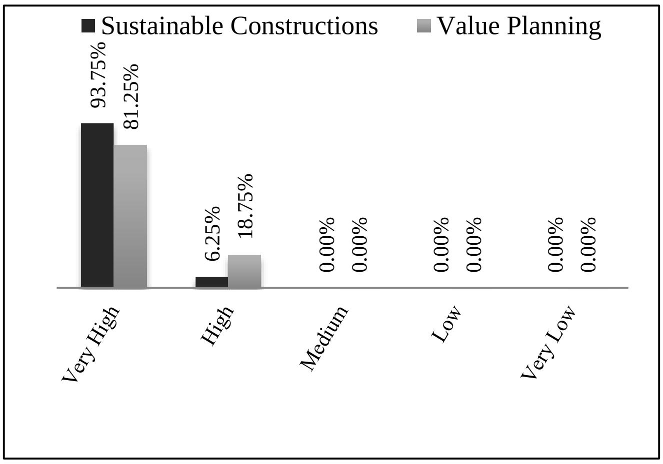

Figure 3: Level of Importance of SC and VP

4.1.3. *SATISFACTION ON CURRENT PRACTICE*

Satisfaction on the current status of practice with regards to SC and VP are being illustrated in Figure 4. More than 80% of the population stated that both the SC and VP application are not at a satisfactory level.

The rationale behind some professionals picking "Satisfied" level on SC 6.25% and on VP 18.75% is merely the influence on the current government policies and technologies being adapted but it are unfair to conclude dissatisfied.

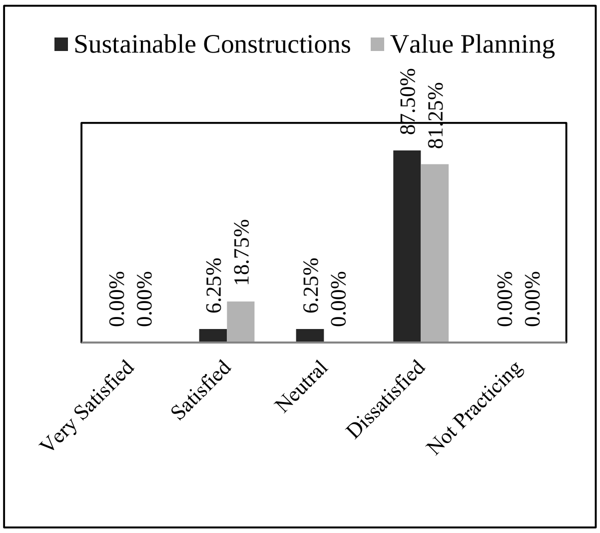

Figure 4: Satisfaction on Current SC and VP Practice

4.1.4. *CURRENT KNOWLEDGE LEVEL*

The SC concept, 68.75% of the total population was on the positive side while on VP concept is 93.75%. Therefore it can be assumed as the knowledge on VP is higher than the SC.

It was revealed that even though the knowledge level is considerably fair the application level is not match with the knowledge level. The reason for the fact is that the people who practicing in management levels in the industry is not knowledgeable as required. Moreover, the relevant knowledgeable experts are more towards in academic instates rather than practicing.

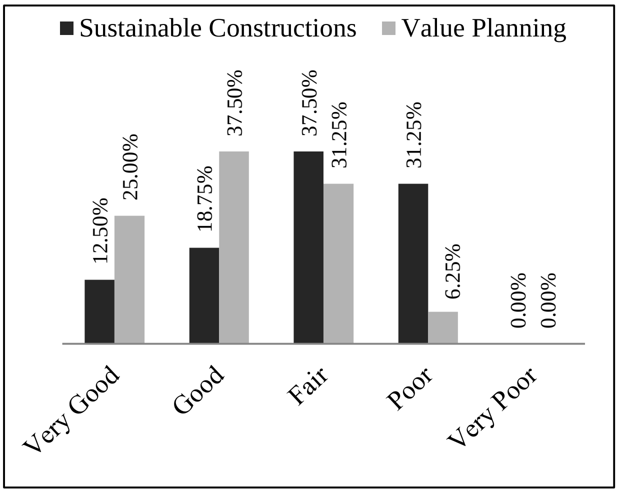

Figure 5: Knowledge Level on SC and VP

4.1.5. *REQUIRED APPLICATION LEVEL*

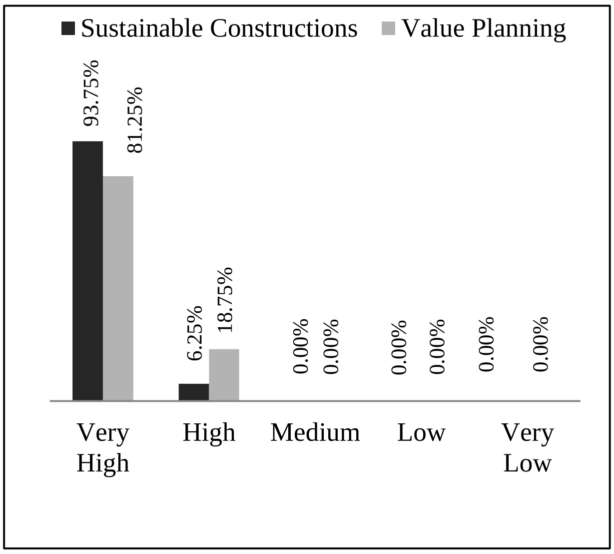

Figure 6: Required Application Level of SC and VP

Figure 6 is the summary of data collected and the analysis under the required level of application. Eventually an overall view certified that the 100% of population of interviewees strongly or averagely believe that SC and VP concept should be applied to the Sri Lankan construction industry more than the current application level. This result came because of the current application level is very low which identified above in "level of application" and "the level of importance" is very high according to the above findings.

4.1.6. *STAGE OF APPLICATION*

Figure 7 provides the analysed data on stage of application. Accordingly, the general idea on experts is that both of these concepts should apply as early as possible or at the planning stage of the project since all these stages are covered in the planning level.

The composition and leadership of the VP and SC teams will be the most important factor affecting the decision making and the success of the process. The identified suitable responsibility and leadership of both SC team and VP team are as follows.

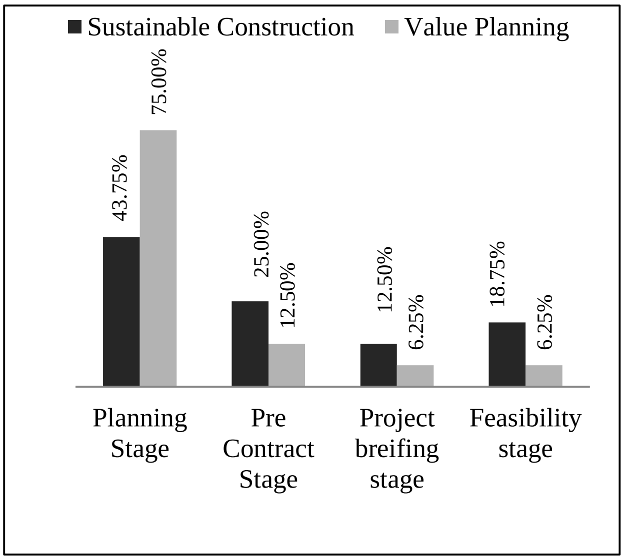

Figure 7: Stage of Application of SC and VP

4.1.7. *TEAM LEADER OF SC AND VP*

Figure 8 established an idea on the suitable leader as an Architect for the SC team and a Quantity Surveyor for the VP team. Most importantly both of those team leaders should have the required skills, knowledge, and experience on the relevant field and able to take the responsibility and the leadership of the process.

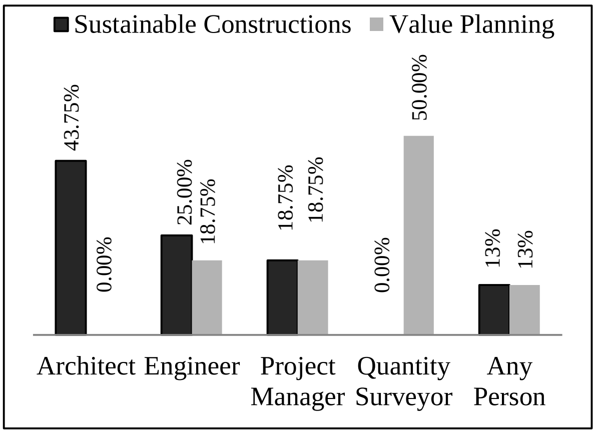

Figure 8: Team Leader of SC and VP

4.2. *PROBABLE BENEFITS, DRAWBACKS AND THE WAY FORWARD OF SC AND VP*

There is no standard or regular process used in sustainable studies and VP studies in Sri Lankan construction sector. What is happening currently is conducting brainstorming sessions at the initial stage of the project and at certain intervals as required as the process goes on.

Findings revealed that number of benefits can be gained by both sustainable and value consideration. Specially, intangible benefits which are hard to achieve in normal construction process can be achieved by the value consideration which leads the end product more compatible with surroundings and also for occupants.

When considering sustainable concept, the benefits include resource conservation, environment friendly in construction and maintenance, improve energy efficiency of the building, reduce total lifecycle cost of the building, reduce wastage of projects initially and operationally, enhance attributes and skills of people who involved in the project, enhance the comfort level and health level of users, increase the employee satisfaction and productivity and reduce strain on the available local infrastructure.

When considering VP concept, benefits include client will gain good value for his money, reduce or eliminate unnecessary costs, reduce whole lifecycle cost, client's and/or users' requirements and needs will be achieved, improve quality of the final outcome and enhance attributes and skills of people who involved in the project.

Barriers and drawbacks of the SC and VP concepts can be identified as lack of awareness of client in SCs and/or value planning, sustainable designs cost more than regular designs when considering the initial cost, lack of government support, more time consuming in the initial stage of design, less knowledge on the sustainable field, consultants do not come up with sustainable proposals and/or VP proposals, shortage of expertise related to the sustainable field, lack of regulation and policies on the SC concept and VP concept, lack of availability of some sustainable or value enhancement technologies in Sri Lanka and lack of guidance on SCs to clients.

Findings on steps to enhance the practice of these two concepts can be filtered as motivation of people who engage in the fields of SC and VM by offering incentives and providing rewards, offering the stakeholders of SC or VP process a percentage of cost saving achieved at the end, arrange competitions and provide certifications and awards for professional-wise and organisational-wise for those who applied SC and VM technique to their projects, obtaining the support of top-level decision makers and arranging free seminars and symposiums to maximise the awareness.

5. FRAMEWORK FOR INTEGRATION OF SC AND VP

The proposed framework shown in Figure 9 is derived from the VM job plan by adding the SC principles during briefing stage. Expected objectives of the proposed framework are, increase awareness of client; top management, study team; design team and the contractor on SC and VP; identify client's needs in terms of SC and VP with main requirements; enhance good communication level and understanding among the team members and other project stakeholders and obtain more commitment of clients to with respect to SC and VP.

The best time for the proposed integrated approach is shortly after appointing the project manager (Consulting Project manager) or facilitator and prior to the selection of the design team. The timeframe of the study depends on basically type, size and complexity of the project. At the end, the objectives should be set in such a way that the plan can be effectively addressed within the allocated time limit since if the study continues for an extended period of time, the approach itself will be opposite to the value concept.

Furthermore introducing each party to others with regards to involvement to the project, specialisation, and key required information will leads to a firm platform to the project. Stakeholders should be aware on the impacts of both project inputs and outputs. A process of having vast communication, transparency, and further improvements should be continued.

Master brainstorming session is the basic workshop involving learning, discussing, explaining, clarifying, and translating sustainable and value issues within the key stakeholders and the project team. All the factors related to sustainable principles and value principles will be taken into consideration at this stage to achieve sustainability and value for money. Predetermined, systematic and sequential approach will be suitable to successful completion of this stage. Finally the concluded aspects will be added to the project brief with the approval of the top management (decision makers).

Conclusions of the brainstorming stage will be made and disseminated at the informational stage. It includes identifying relationships between sustainable and value drivers. This should address the clients' needs, allocated budget limit, allocated time limit, overcoming of barriers and challenges and the practicability. Development of guidelines, tools and techniques with standards, benchmarks, sustainable and value specifications will be a key concern of this step.

In the next step priorities for sustainable principles should be defined. The suitable and successful criteria are the most accepted sustainable values by the design team experts. Sustainable values can be added to the value criteria under three main sub categories as environmental, economical and social.

Creativity phase involves with generation of innovative ideas and possible alternatives as many as possible in order to achieve each function identified in previous stages. These ideas should be in line with the sustainable and value principles as discussed above. Each idea should be considered and written down in a systematic order. Then the design team carefully evaluates each idea and comes to an agreement where the project objectives should be clearly focused.

In the development stage the selected ideas and alternatives in the previous phase will be developed into a practical base. Selection of best alternative is again a part of this step. Presence of the client (project sponsor) will be more effective in this phase to make an assessment considering the feasibility of these ideas when implementing. Finally the best idea will be developed with the help of the expert team members considering all the aspects and possible issues.

In the decision making and recommendation phase the final decision is taken after considering all the facts and recommendations being presented. Advantages and disadvantages of all proposed and listed ideas, rationale for selecting the final idea and reasons for rejecting other ideas are needs to be revealed.

Preparation of an implementation plan including all ideas and alternatives accepted by the team in previous stages is the key task of this phase. This is the phase where all the above efforts come to a reality. If all the previous steps have been completed accurately, there is no margin of error in the implementation phase.

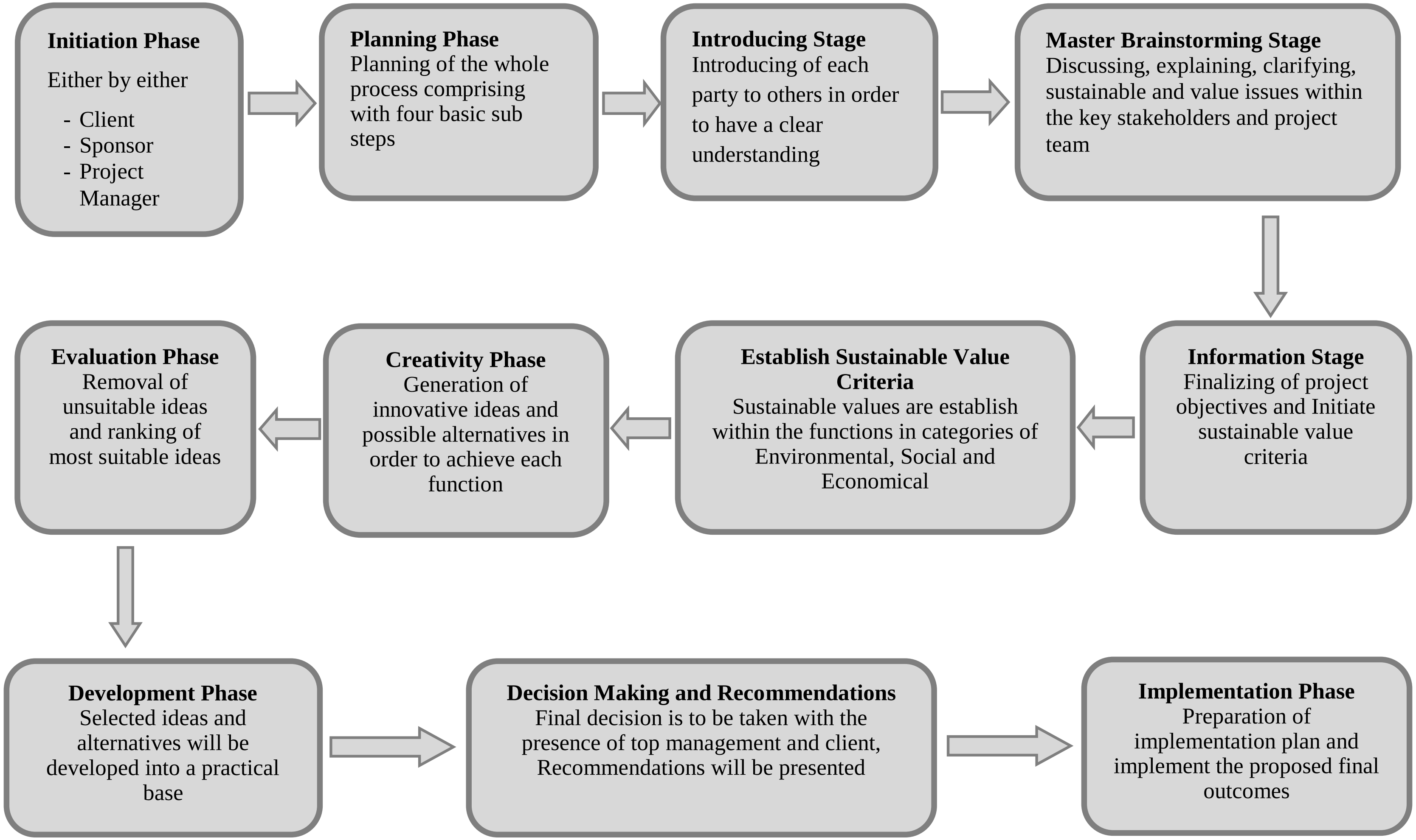

Figure 9: Proposed Final Framework for Integration of SC and VP

5.1. AVOIDANCE OF IDENTIFIED ISSUES BY THE PROPOSED FRAMEWORK

Proposed framework provides understanding and implementation of principles of VP and SC in Sri Lankan construction industry to the client and other stakeholders at the initiation stage and/or planning stage as well as latter stage. It will help the establishment of sustainable development concept to the project.

At the tender evaluation stage, if reasonably high marks are awarded for the bidders who come up with SC proposals and value enhancement proposals, it will increase the contractors concerns, knowledge and awareness on SC and VP. This will help overcome two identified barriers, contractors' unwillingness and unawareness on these concepts and the current poor application of these disciplines.

Team leader will demonstrate the client on VP and sustainability application, outcomes, and benefits it can gain. This will clearly enhance the awareness of clients in the industry on both VP and SC concepts. Through the brainstorming session in stage four, each team member will become aware of special expertise area and experiences of others. This will enhance the knowledge level of experts in the industry.

As two disciplines are to be addressed in a single process with a single team, it helps enhance the knowledge level and skills of Value experts on SC aspects, and to enhance the knowledge level and skills of SC experts on VP aspects.

Integration of SC principles into VP approach will results a hybrid approach including two benefits from one process. Implementation of both as a one exercise shall provide far more effective opportunities in implementing the value for money in the project. Moreover it will help shift the thinking of all stakeholders from sustainability to sustainable value and cost to value. Ultimately it will save time and money for not having two approaches separately. This will overcome the major barrier of cost factor identified previously.

6. CONCLUSIONS

It is established that VP can be upgraded to keep its competitiveness while enhance the performance of sustainable concept and expand the implementation status throughout the country in delivering value for clients' money. Findings revealed that even the level of importance is a very high, current situation of SC and VP implementation in the Sri Lankan construction sector is not at a satisfactory level. Moreover it was found that there is considerably good expert knowledge in the field. Consequently, the most appropriate team to be involved in the process has been identified. Poor awareness, lack of government support, initial time and cost factor were identified as the main barriers for the integration. Thereafter incentives to accelerate the implementation were assessed.

Development of a framework for integration of SC and VP for construction projects has been done by assessing the feasibility of using the value concept to implement Sustainable concept, identifying VM techniques, identifying the capability and limitations of SC and VP, identifying the enhancers and barriers to SC and VP and by using the VM job plan as a base. The main perception behind was defined sustainability as a one value to achieve from the project in the value concept therefore sustainable agenda becomes a value to achieve through the process.

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ENVIRONMENTAL MANAGEMENT SYSTEM (EMS) PLANNING IN MANUFACTURING: FACILITIES MANAGEMENT PROSPECTS

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ABSTRACT

The increasing consciousness of sustainable development and reconciling production with ecosystem conservation have fostered the adoption and implementation of Environmental Management System (EMS). This study investigates the process and factors that affect in EMS planning. Previous research mainly focuses on environmental management practices and its performance towards different sectors. It was identified that minimum attention is given to planning of EMS at corporate level. Thus, this study explored the corporate EMS planning process in Sri Lankan manufacturing industry. This is an area where facilities managers can contribute in manufacturing facilities. This paper reports on case studies of three private sector manufacturing industries, which were using up to date environmental management practices. Data was collected by interviewing three participants from each of selected manufacturing firms. Based on the case study findings, a framework was developed for EMS planning. This includes six stages starting from strategy formulation to system implementation and evaluation. The developed framework will lead to an effective EMS planning practice that could be used in Sri Lankan manufacturing industry.

Keywords: *Corporate Environmental Management; Environmental Management System; EMS Planning; Manufacturing Industry; Sri Lanka.*

1. INTRODUCTION

The extension of economic growth in business through globalisation has often been associated to issues that are threatening to the environment. As such, many corporations have realised their social responsibility and voluntarily succumbed themselves to international standards pertaining to environmental management (Watson, 2000). Hence, environmental considerations in organisations are likely to form an integral part of commercial normality and indeed competitiveness in the future (Pun and Hui, 2001). A competitive advantage can be achieved not merely by keeping abreast of environmental developments, but also by initiating change with an organisation and responding with new environmental friendly products and production process. Indeed, growing consumer awareness and environmental pressure groups are likely to ensure that firms which do not take action on the environmental front will lose market share (Montabon *et al.,* 2000). Thus, manufacturers that can simultaneously provide quality and environmental friendly products tend to have a general potential of capturing larger market shares and returns.

Facilities managers today similar to other managers are expected to become more environmentally responsible (Montabon *et al.*, 2000). Pitt and Trucker (2008) defines FM as the integration and alignment of the non-core services including those relating to premises, required to operate and maintain a business to fully support the core objectives of the organisation. Nowadays, dedication of FM organisations to new developments seems to be the way to stay in business, constantly exceeding customers' expectations and adding value to the core business of the client organisation (Mudrak, 2004). In that, facilities managers should work in par with the top management to practice environment management within facilities. This

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paper looks into environmental management and its planning process in manufacturing organisations in Sri Lanka.

2. LITERATURE SYNTHESIS

An Environmental Management System (EMS) is a structured approach to address the environmental bottom line. It is defined by the British Standards Institute (1994, p.6) as; "the organisational structure, responsibilities, practices, procedures, processes and resources for determining and implementing environmental policy." With reference to the International Organisation for Standardisation (ISO, 2010), an EMS is a systematic approach to dealing with the environmental aspects of an organisation. It is a 'tool' that enables an organisation of any size or type to control the impact of its activities, products or services on the natural environment.

An EMS, therefore, generally follows the adoption of an environmental policy. According to Maier and Vanstone (2005), the environmental policy formally outlines a company's commitments to environmental management and commonly includes commitments to reduce waste, pollution, energy and resource use, sets objectives and targets and reviews the company's environmental performance. This policy starts with EMS planning phase.

EMS planning is the process of identifying a portfolio of environmental strategy and business process and determining a better alignment of both (Pun *et al.*, 2002). The planning can assist an organisation in executing its business plans and monitoring its environmental performance and goals. The outcomes are greater understanding of the EMS opportunities and a shared view of the EMS benefits and constraints across the organisation. Nevertheless, the EMS planning is a complex and continuous process which consists with four major actions, namely, 1). Identify aspects and impacts from facility activities, products, and services; 2). Review legal requirements; 3). Set objectives and targets; and 4). Establish formal EMS program (Washington, 2007). It is influenced by a host of socio-technical parameters whose behaviour and interactions are not well understood. According to Pun's *et al* (1998) view the effectiveness and efficiency of the process also rely largely on stable environment and quality planning resources. Previous studies have found that different planning methodologies may lead to various planning results and decisions. Many attempts at EMS adoption do not necessarily lead to align EMS planning with the corporate objectives, and identify critical processes and procedures according to the pressures bearing on their unique core business (Maxwell *et al.*, 1997). Besides, there are number of common organisational factors that are affecting to the environmental management system planning as presented in Table 1.

Table 1: Divers and Barriers for EMS

Drivers	Industrial Barriers	Organisational Barriers
Organisations: The drivers within organisations include management, staff, parent company, and shareholders.	Capital costs: This mainly comprises with funds for major and minor environmental improvements and the expected internal rate of return on all capital projects.	Attitudes of personnel: Personal attitudes like disengaged, parochial interests, effect more critically since those attitudes directly cause the organisational line of business.
Market: Most consumers now demand environmental loyalty before they purchase products. Industries, therefore, are prompted by the market to adopt new strategies towards the environment.	Community concern: In an emergency situation, community must concern on the perception of risks associated with the business.	Quality of communication: "Distance" between top management's espoused commitment and action throughout the organisation.
Social forces/Community: A community can demand the existence of good EMS in an organisation that they feel is a threat to the environment and their existence. In particular, the activities of environmental non-governmental organisations are	Regulatory constraints: Since EMS planning works with regulations, standards, operating permits, there's a barrier to make required	Administrative heritage: Improper establishments of Standard operating procedures and assumptions about running the business also can be a prioritised

Drivers	Industrial Barriers	Organisational Barriers
becoming very vocal and serve as a key driver of EMS.	changers without legal consent.	factor in organisational EMS planning.
Financial: Financial institutions and insurance companies these days demand the existence of an effective management system like EMS in order to acquire and get insurance.	Information: Difficulty of collecting appropriate data and inadequate measurement tools.	
Regulatory Institutions: Porter (1990) argued that government regulations may serve in practice as a stimulus to both economic growth and cleaner production.	Technical knowledge: Physical, chemical, and biological uncertainty, inability to eliminate some risks or effects.	
Source: Zutshi and Sohal (2004)	Source: Post and Altman (1994)	

While above mentioned drivers and barriers influence an EMS planning process, it is seen increasing recognised in the manufacturing industry. For example, Stipanuk (1996) found in their study that almost all manufacturing firms have planned their in-house EMS or used efforts on protecting the environment in manufacturing firms with varying degrees of intensity in the past few decades. Hence, there is a necessity for facilities managers who engage in manufacturing sector to be knowledgeable about EMS planning process and take a lead role in implementing this together with the company top management. With this, this research study aimed to identify good practices of Environmental Management System (EMS) planning processes in Sri Lankan manufacturing organisations together with its drivers and barriers in order to suggest an effective procedure for EMS planning in manufacturing sector.

3. RESEARCH METHOD

This study has adopted qualitative research approach, the essence of which, according to Wigren (2007), consists of focusing on understanding the naturalistic setting, or everyday life, of a certain phenomenon by the investigator. Qualitative methods are essentially descriptive and inferential in character and focus primarily on the kind of evidence that will enable to understand the meaning of what is going on. Accordingly, among various approaches available in the qualitative approach, case study (Yin, 2003) has been selected.

The case study research method provides an in-depth investigation by studying ‘cases’ in an uncontrollable environment. According to Yin (2003), case studies are the preferred strategy when ‘how’ or ‘why’ questions are being posed, when the investigator has little control over events and when the focus is on contemporary phenomenon within real-life context. Considering these points, the case study method was seen as suitable for this study.

In this study, cases were selected from manufacturing industries which were adapting EMS Planning. Accordingly, three manufacturing firms which engage in EMS planning were selected. From each case three semi structured interviews were conducted with three representatives from top management, middle management and employees. Altogether, 9 interviews were conducted and each normally lasted for 30 minutes to 45 minutes. Table 2 provides the case studies and interviewees’ details.

Table 2: Case Study Description

Organisation	Organisation A	Organisation B	Organisation C
Type of Business	Tobacco Manufacturer	Biscuits Manufacturer	Dairy Food Manufacturer
Interviewees	▪ EHS Manager ▪ Shift Manager ▪ Quality Executive	▪ QA Manager ▪ System Manager ▪ Assistant System Manager	▪ EHS Manager ▪ Assistant QA Manager ▪ QA Executive

Key themes (codes) emerging from the findings were identified within each case and replication of findings were tested using 'cross-case analysis.' The research results are presented and discussed next.

4. RESEARCH FINDINGS

Research findings from the case studies are presented here in two sections: Environmental Management practices in Sri Lankan manufacturing firms; and, Drivers and barriers of EMS planning.

4.1. ENVIRONMENTAL MANAGEMENT PRACTICES IN MANUFACTURING

The empirical study revealed that Environmental Management (EM) of an organisation provides a framework for managing environmental responsibilities efficiently integrating the company's production cycle and the overall operation. Considering the environmental management practices in manufacturing industry, it can be identified that it is a crucial factor which affects each and every step of the production cycle. Starting from the raw material reception, all the raw materials must be fitted to the pertaining parameters or standards of the organisation which emphasis the aptness of them to the environment. For example, EHS Manager of Organisation A emphasised that, "*since this company provides a consuming product to the end user, we are highly concerned about the environmental management in our production cycle. We mainly consider about the energy, electrical, fuel, vehicle emission, transportation, logistics, water and waste*." Generally, manufacturing firms are operating their regular tasks with the machinery works where emission, effluent, waste and odour are the major discharging entries that arise as consequences of electricity, water, fuel and other raw material usages. According to QA Manager of Organisation B, "*first, we conduct an aspect evaluation and prepare process maps and flow charts. Then check each and every process steps and prepare environmental aspects and relevant impacts. It called as the aspect register. There we identify each and every aspect of the organisation with their impacts*." As per EHS Manager of Organisation C, *"in the area of packaging, an active and fruitful environmental friendly mechanism is needed and it results to the whole environmental improvement."* These quotes show how each organisation aligns EM with their production cycles.

The responsibilities of the all management levels include identifying ways for the organisation to improve its environmental performance; setting objectives and targets; and monitoring and evaluating implementation. The organisation should explore its in-house expertise in forming the task group, with the participation of top management, middle management and the employees. Case studies revealed duties and responsibilities of these three levels as depicted in Figure 1.

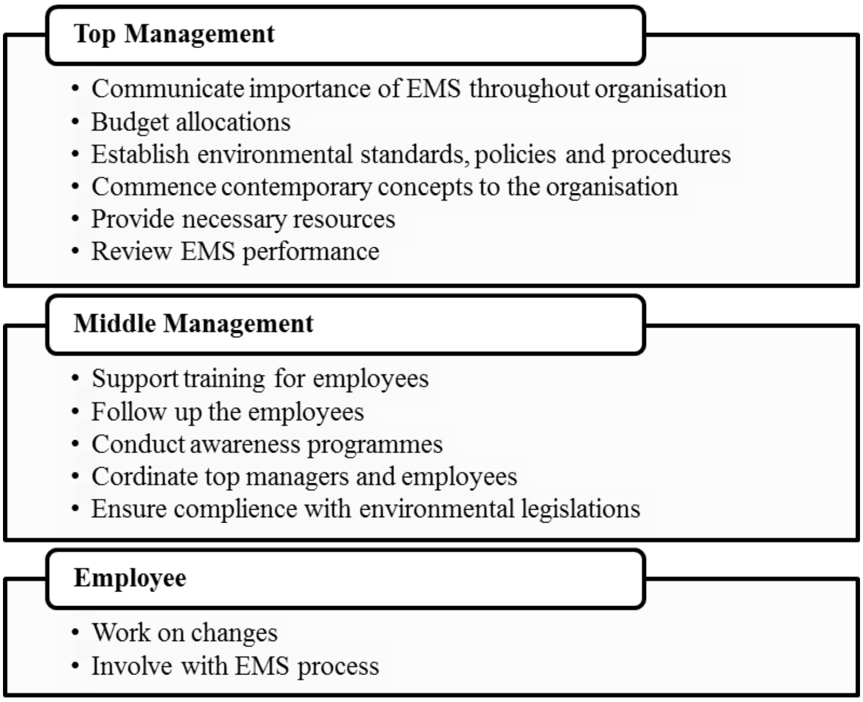

Figure 1: Corporate Responsibilities of EM Practice

Key difficulties faced by management during and after the implementation of EMS include issues with human resource management, changing attitudes and inadequate training in terms of employees. Another significant difficulty as per the QA Manager of Organisation B was paying attention to legal and regulatory factors that are pertaining to the manufacturing industry.

To introduce EMS within the organisations, each organisation practice different strategies. These could be group into three areas and listed as given in Figure 2. Factory-based EM strategies comprised with the standard measurements of ISO 14000 under the criteria of air emission, soil protection, waste management, effluent and eco efficiency. Strategies which aligned with personnel and resource consumption of the organisation were identified as community-based EM and Resource-based EM respectively.

Factory based Environmental Management

- *Environmental management based on the ISO 14000 standards*
  - ✓ *Air emission control*
  - ✓ *Maintain water and discharge of waste water*
  - ✓ *Protect soil and ground water level*
  - ✓ *Eco – efficiency*
  - ✓ *Waste management*

Community based Environmental Management

- *An approach to environmental protection that starts with a local environmental problem and involves all the needed persons and organisations*
- *Jointly manages the resource through partnerships of governments, businesses, non-government organszations and citizens.*
  - ✓ *Conduct periodical training programmes*
  - ✓ *Invite guest lecturers to training programmes*
  - ✓ *Conduct posters, painting and art programmes to aware our stakeholders*

Resource based Environmental Management

- *Environmental management strategies which align with the resource consumption of the organization*

Figure 2: EMS Strategies

Through the study it was apparent that these EM Strategies tend manufacturing industries to provide an overall framework and direction for environmental management.

4.2. DRIVERS AND BARRIERS FOR EMS PLANNING

Case studies identified internal environment and external environment factors. Internal environment factors were mainly based on organisation resources, technological capacity, organisational culture, management systems and employee morale. In terms of external environmental factors, interviewees agreed on market, financial and social related drivers but were unable to provide specific examples. In terms of regulatory drivers, they mentioned about Environmental Protection License. This aims to prevent or minimise the release of discharges and emissions into the environment from prescribed activities in compliance with national discharge and emission standards and develop an approach to pollution control that considers discharges from prescribed processes to all media (air, water, land) in the context of the effect on the environment.

Interviewees discussed on industries barriers starting with capital costs. Management commitment and analysis was seen as a must, before allocating capital for EMS planning. Therefore, in the planning stage of an EMS the organisation must highly concern on the capital cost that need to be allocated in environmental management projects. This enables the firm to determine funding sources and feasibility of those projects. Although, the relevant laws and regulations act as a driver in EMS planning in manufacturing organisations, they become barriers due to constraint in obtaining certificates and license. Similarly, community requirements could both act as a driver or a barrier as per the interviewees.

Further barriers were identified through case studies. One significant barrier was inadequacy of relevant information and resources which agitates the process of how to plan EMS and how to integrate with the organisational internal and external forces. The Shift Manager of Organisation A confirmed that "*overall, we have an inadequacy of information on relevant activities regarding the EMS planning and there are no ideal solutions for certain problems*." Further, technical knowledge was seen as a significant in the process of planning an EMS. Even in the stage of planning an environment management system, organisation have to have an outstanding technical knowledge for the purpose of providing a better procedure of environmental management. The Shift Manager of Organisation A stated, "*to update all levels of employee's knowledge frequently we need a high quality communication throughout all the personnel levels*." Thus, in the planning stage of environmental management system, all levels of organisation must have a communication system which captures the whole management levels and the employee levels.

Resistance to change was another barrier revealed through the case studies. At their worst, these can prevent the introduction of best practice altogether. Thus, senior management should be flexible with dynamic situations of the organisational changes. Top managers' commitment should be very strong in the process of EMS planning as if it goes wrong, that may cause to the deficiency of the whole process. As per the view of Quality Executive of Organisation B, "*this is a family owned business that has 30-40 years' experience. So it is difficult to convince them about the modern theories*." Hence, most of the organisations are congregated with the strong views and opinions of the administrative intensity. Planning an EMS must be liberated from the external environmental forces and internal environmental forces as well. Hence, to overcome these barriers, organisations adopt practices such as establish good communication flow among all the management levels; monitor objectives; conducting awareness programmes and develop a network of environmental co-ordinators in all departments of the organisation.

4.3. EMS PLANNING FRAMEWORK

Considering the current industrial practice of EMS planning, most of the organisations were undertaking processes unique to them starting with formulating environmental strategies to EMS impact evaluation. However, it was possible to identify a common framework by capturing good aspects of the studied organisations. Figure 3 offers the complete framework for EMS planning that could be followed by manufacturing organisations. It has six phases starting from formulation of relevant environmental strategies. Next step is to determine the EMS team and their responsibilities. The third step is to identify drivers and barriers for EMS and prepare action plans. In the fourth step, organisational infrastructure is set. The next step is implementations followed by the final step which is reviewing the EMP plan.

By having EMS planning in place, case studies revealed following organisational benefits such as Reduces operating costs through waste reduction; Energy conservation and other savings; Provides a structured framework for identifying and meeting regulatory requirements; and, Demonstrates competitiveness with other competitive manufacturers. A proper plan of EMS could help organisations to improve their operation performances, since EMS regulates and enhances companies' communication of goals, procedures, environmental impacts, and solutions process. Moreover, it can help managers in eliminating the instances of redundancy in day-to-day efforts. Also EMS improves its marketing with customers, investors, creditors, suppliers, employees and the public.

For end users, several benefits were noted. When there is an EMS planning process, organisations can reduce violations of employee-employer relationships and there can be a superior legal bond with the relevant legal bodies due to the environmental friendly production cycle. Thus, through a proper planning of environmental management system the customer who consumes the products also can obtain several advantages like ability to consume green products, get aware about the environmentalism while receiving environmentally protected and healthy product for the price they expend. The conclusions drawn from this study are prioritised next.

5. CONCLUSIONS

EMS planning in manufacturing industries is significant since, all the environmental impacts and aspects in manufacturing industries very much affect to their environmental performance. When it comes to the practical level in the industrial sector, organisations specially focus on the manufacturing or the production cycle which emits waste, gases, fumes, odour and effluent to the environment.

Considering the corporate level of EM, case study findings disclosed that main corporate responsibilities are centralised within the top management, middle management and employees with specific duties and functions in order to guide their subordinates towards the practice of EMS.

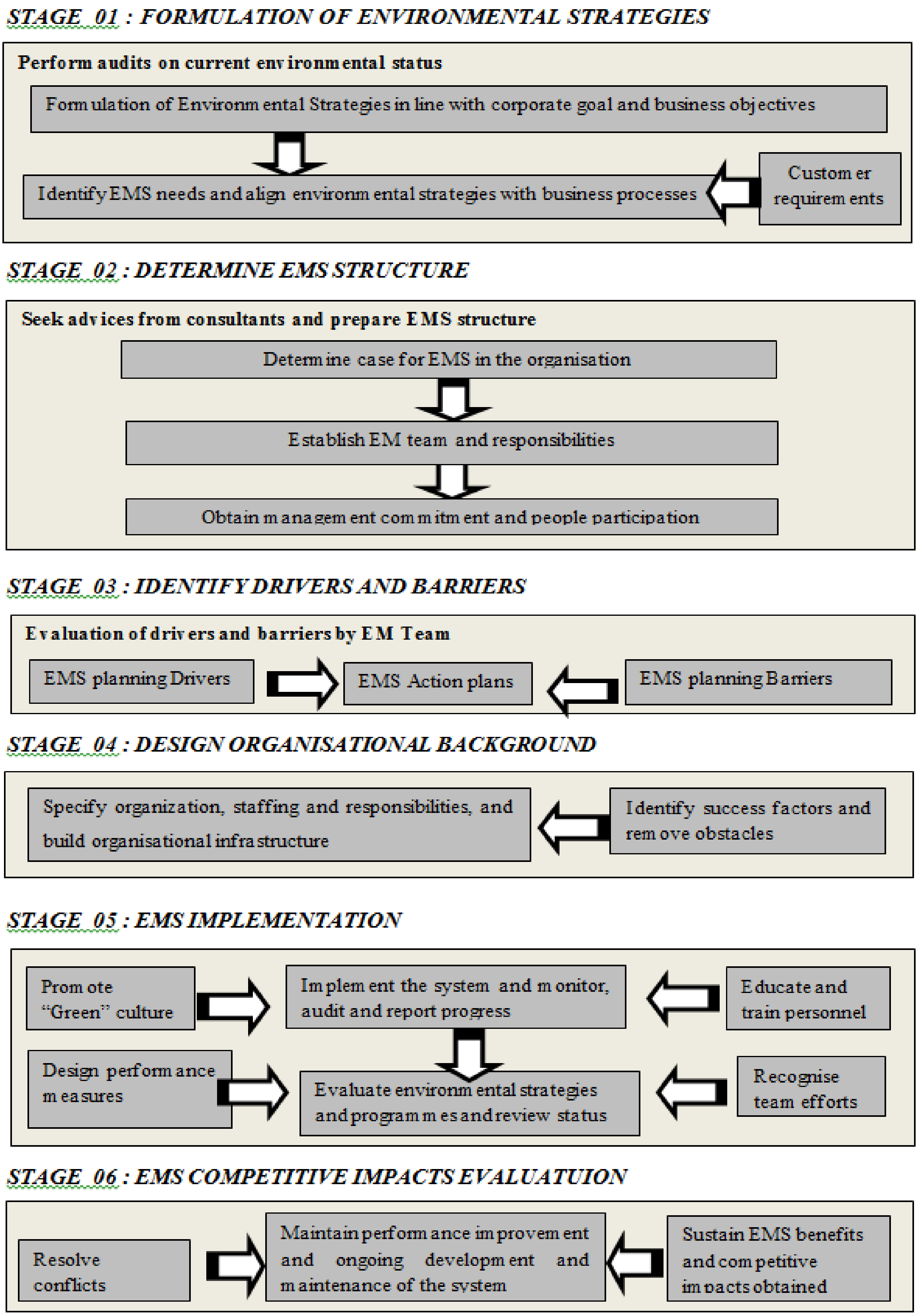

Figure 3: EMS Planning Framework

Three major EM strategies that are pertaining to the manufacturing industry were identified as factory-based EM, community-based EM and resource-based EM. Even though, the literature reviewed that Plan-Do-Check-Act are the four main steps in the process of EMS, the industrial practice comprised with three main steps call planning, implementing and monitoring. Pertaining to this whole EM process, EMS planning was identified as the key step which directs the whole EM process towards the organisational ultimate goal of best practice.

The study offered a framework for EMS planning capturing the common processes followed by the case studies organisations. This framework can offer a better alignment of EMS planning process with business objectives and strategies. Overall, it is believed that the framework offers EMS planning implementations a reference point. Through following these steps in EMS planning the organisations can achieve competitive advantage and improve the company image with improved customer relationships.

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EQUIPMENT SELECTION FACTORS OF INTEGRATED BUILDING MANAGEMENT SYSTEMS (IBMSS) IN SRI LANKA

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ABSTRACT

Management of facilities has become a complex task involving multitudes of disciplines. With increased awareness for efficient building operation, building owners and operators are looking for means to reduce the operational cost and to ensure the proper functionality of buildings and building services. To manage an organisation in an effective and cost-efficient way, these systems can be integrated into a single interface control solution called Integrated / Intelligent Building Management System (IBMS). Hence, in an intelligent building, IBMS acts as a complete information delivery system that monitors and controls a variety of mechanical and electrical systems and equipment such as such as lighting, Closed Circuit Television (CCTV), access control, fire detection, air conditioning, water management, elevator management, cark park management, etc. at an optimal level of efficiency. However, building systems and the equipment for the IBMSs should be carefully selected as those components have major contribution towards the overall performance of an IBMS. Hence, this research was carried out with the aim of investigating the factors that should be considered in selecting systems and equipment for IBMSs. A comprehensive literature survey, a preliminary survey and case study method was adopted to achieve the aim of the research. The required data were collected through semi structured interviews conducted among IBMS contractors of selected cases. The collected data were analysed, using code based content analysis. According to the findings, 'higher efficiency', 'cost, 'improved safety' and 'enhanced reliability' are the four major factors that should be considered in system and equipment selection. With the high demand and awareness of IBMS, it is fast becoming a part of facilities management and operational strategy in the organisations. Therefore, the careful consideration of above selection factors in designing would ensure the maximum performance of the IBMS.

Keywords: *Integrated Building Management System (IBMS); Sub Systems and Equipment; Present Status; IBMS Selection Factors; Sri Lanka.*

1. INTRODUCTION

Integrated Building Management System (IBMS) is a complete information delivery system that monitors and controls a variety of systems and equipment at an optimal level of efficiency. Ochoa and Capeluto (2007) stated that intelligent buildings are those that combine both active and passive intelligence, active features and passive design strategies, to provide maximum occupant comfort by using minimum energy. An IBMS typically consists of a personal computer-based graphic user interface, modular direct digital control (DDC) panels, DDC-based variable air volume (VAV) box controllers, microprocessor-based 'gateways' to interface integrate with other systems, and either a copper or a fibre optic communication network (Langston and Lauge, 2002). Panke (2002) introduced a brief list of events that should serve as a guide to the overall BMS project. According to author, these events are initial concept, information retrieval, design and system selection, field survey, candidate buildings, contract documents preparation, contract, installation and training, acceptance as well as operation and maintenance. Among them, the initial design and system selection plays a major role in assuring the overall performance of an IBMS. Therefore, several important factors should be carefully considered before selecting the systems and equipment for the

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IBMSs. However, literature on this area is limited and therefore an attempt was made in this research to fill the above gap by investigating the system and equipment selection factors of IBMS.

2. INTEGRATED BUILDING MANAGEMENT SYSTEM (IBMS): AN OVERVIEW

Over the past thirty years, the designers of Heating, Ventilation and Air Conditioning (HVAC) systems have gradually shifted towards the use of digital computers, replacing direct manual controls and simple analogue feedback loops such as thermostats (Langston and Lauge, 2002). This was the introductory stage of BMSs. Then the high technology concept of IBMS was introduced in the United States in the early 1980s (Coggan, 1996). The desire for an effective and supportive environment within which an organisation can reduce energy consumption, improve worker productivity, and promote maximum profitability for their own business has further stimulated the growth of highly adaptable responsive buildings integrated with IBMSs (Clements-Croome, 2001 cited Wong and Li, 2009).

IBMS denotes to a system where components communicate with each other and generally implies some form of central administrator, which permits monitoring and controlling of the building from a single point (CIBSE Guide H, 2000). Through the system integration, entire IBMS can be operated from a single head end personal computer, where the operating staffs has to learn about one set of operating software. Integrating the systems, with thorough understanding on the needs of the facility and the advanced planning process shall facilitate undisturbed conditions in the building and sustainable development through minimised energy consumption, first-class security and significantly lower life cycle costs. Further, intelligent buildings combine both active and passive intelligence to provide maximum occupant comfort (Ochoa and Capeluto, 2007). Proper BMS provide regulating output in response to varying indoor and outdoor conditions and also provide closer temperature and humidity limits in production areas for product quality. According to Colliers International (2007), building owners get benefited as IBMSs result in higher retention of tenants and rental returns due to less complaints and better comfort levels. Further, improved tenant relations are possible due to reduced complaints. Moreover, facilities managers can ensure more reliable plant operation and HVAC control from a central location. For the Service Contractors, the IBMSs allow remote service access for quicker response to its faults. It also permits more efficient diagnostics of plant faults and allows for historical performance data to be retained.

3. STRUCTURE AND FEATURES OF AN IBMS

The development of larger integrated systems depends on the existence of communication protocols which allow devices from different sources to communicate with each other. Therefore structure or system architecture of IBMS is based on the organisation of IBMS and the networks that monitor and control the entire building operation. CIBSE Guide (2000) has identified the entire communication procedure within the BMS in three different layers (Refer Figure 1). The sensors and actuators take place at the field level while intelligent controllers sit at the automation level. The head end supervisor has the access to all systems at field level. The management level accesses information from the automation level and has the access to a wide area network. Accordingly, it can exchange management information with independent systems within the same building or with other buildings. Though this structure has the advantage of organising network traffic efficiently, it requires the additional complication of linking the three levels. Therefore a single network model is sufficient for many applications.

According to Panke (2002), there are five basic hardware components that are used in IBMSs such as sensors, actuators, microprocessor-based field panels (controllers), communication links, and a central operator station. Sensors transmit information that defines a single operating condition, such as temperature or pressure. This information is supplied to the field panels (controllers) for monitoring or decision-making purposes. Actuators are the mechanical interfaces that implement actions initiated by the field panels in accordance with the inputs received. Information relating to the entire process has transmitted over the communication links to a central operator station. The next important section of an IBMS is the network that connects several devices together and communicates within the system. Physical medium and protocols are the main two parts of a BMS network. Protocol is a language that rules the entire communicating signals through the physical medium. Different transmission systems and media use alternate physical mediums including twisted pairs, voice grade telephone lines, coaxial cables, electrical power lines, radio frequency, and fibre optics for communications between the field panels and central operator station.

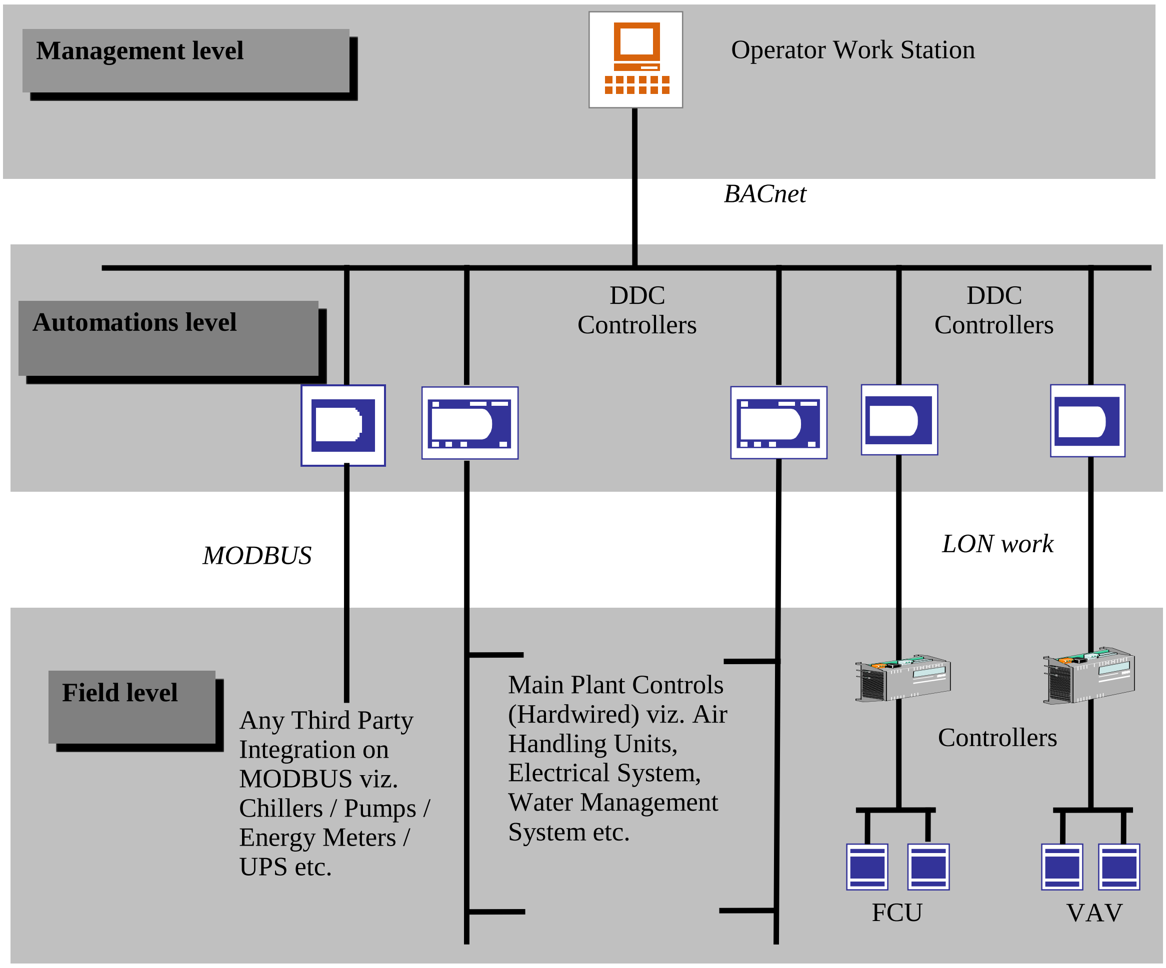

Figure 1: Typical Structure of an IBMS
Source: Seimens (2008)

According to Siemens (2003), IBMSs are open to operation as open system architecture is widely supported, making it possible to integrate third-party systems at all three levels of the system. Further, a well-designed IBMS provides clear user guidance and graphic-based display to take account of ergonomic principles. Innovative web technology is used both at the automation level and the management level. Through these web accesses, fault messages can be received and acknowledged with cost-efficient standard equipment such as Web-Pad, PC or mobile phone. Then system can be kept up to date all times irrespective of the location. As Siemens (2003) pointed out, due to technological advances and improved project handling, costs per data point are falling steadily and therefore, IBMS is economical in every phase. When concerning about the life cycle cost of the plant, economy-minded building operator focus on the sensible start-up costs, efficient and cost-effective support during operation plus flexible service options.

4. SUBSYSTEMS AND EQUIPMENT SELECTION FACTORS OF AN IBMS

A well-planned control system offers improved management of building services and can form the core of an integrated facilities management system, covering other building-related services (Jankovic, 1993). Mostly, intelligent building control products are designed to provide environmental control, mobility, communications facilities, fire protection and security in the building (Wong and Li, 2009). However, Figure 2 shows various equipment and sub systems that can be integrated with IBMSs.

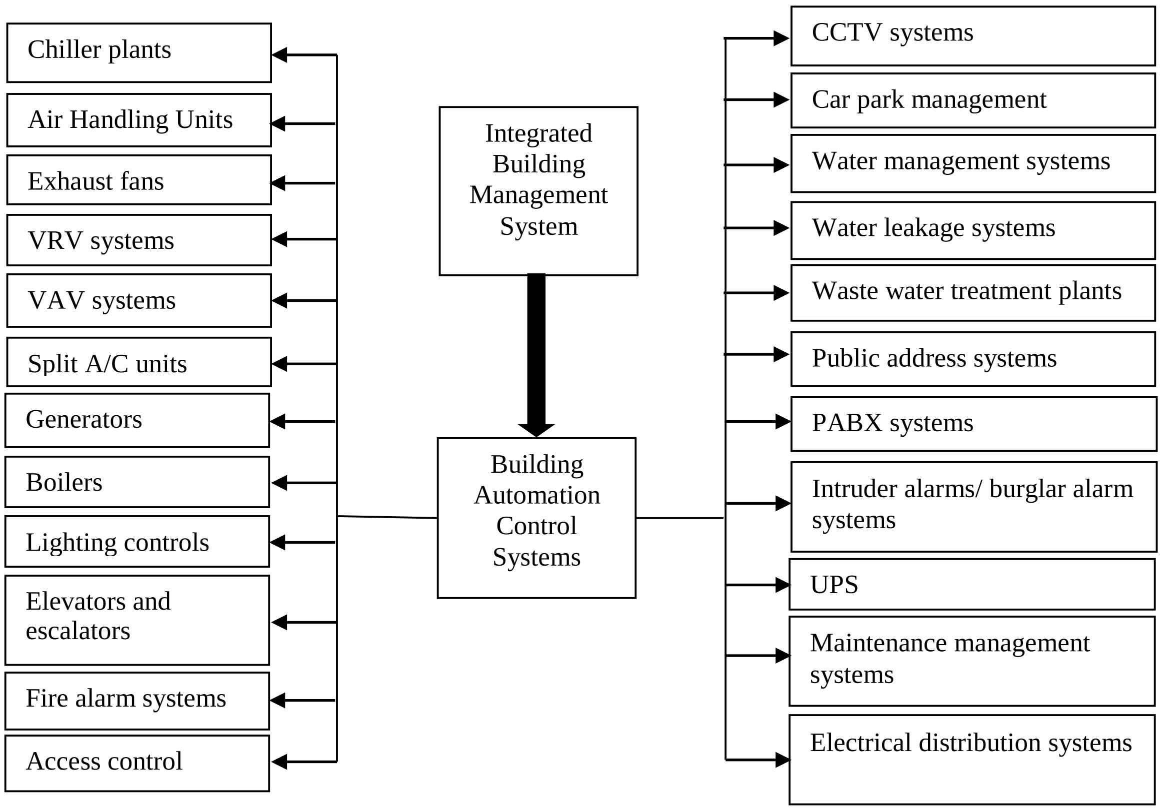

Figure 2: Sub Systems that can be Integrated to IBMS

The aim of building intelligence is to help enterprises, facilities managers and occupants alike realise goals cantered on cost, comfort, convenience, safety, long-term flexibility and marketability. Therefore, intelligent buildings should be sustainable, healthy and technologically strong, meet the needs of occupants and business and should be flexible and adaptable to deal with changes. In order to cater these needs, the building systems and the equipment should be carefully selected and integrated with the IBMS. Therefore, having proper knowledge on the factors that should be considered in selecting those will enable the facilities managers to successfully design and install an IBMS. According to CIBSE Guide (2000), selection of the suitable physical medium should be based on the initial cost, efficiency (Scan rate), reliability, maintainability, expandability, and compatibility with future expansions. As stated by Wong and Li (2006), work efficiency was perceived as the most important core criterion for the selection of IBMSs. Further, service life and operating and maintenance costs were regarded as the two most crucial sub-criteria in various IBMS systems. According to the researcher, long-term expenses are also of major concern of many owners and decision makers. Moreover, researcher pointed out a strong need for the consideration of providing a comfortable and productive working environment to satisfy the physiological needs of the occupants in buildings.

5. RESEARCH METHODOLOGY

A three step approach, i.e. a comprehensive literature review, preliminary survey and case studies were employed in achieving the aim of the research. First, the system components, protocols, hardware, sub systems and equipment, benefits and other fundamental information of IBMS were identified through the literature review. The main objective of the preliminary survey was to get opinions of experts to inspect and study about IBMS prior to the interviews. Furthermore, it was aimed to gather expert opinions to identify and list out selection factors of sub systems and equipment. The preliminary survey was conducted by interviews within five IBMS experts in the industry gathered their opinions to develop interview guideline for the detailed study. This study is an exploratory type research and therefore, case study approach was selected to achieve the aim of the research. The unit of analysis or the case in this research was contractor organisations who design, supply, installation, testing and commissioning IBMSs in Sri Lanka. Three contracting organisations, which have completed lots of IBMS projects and who have more than five years of experience in the field of IBMS were selected in order to verify the list of equipment and system selection factors identified after the expert survey. After developing interview transcripts, semi structured interviews were conducted for the data collection. Code-based content analysis was used for the analysis.

6. RESEARCH FINDINGS

After identifying the systems and sub systems which are integrated with IBMS, a list of selection factors were identified based on the literature findings. Then some changes in the list of sub systems and equipment were also done based on preliminary survey findings. Variable Air Volume (VAV) System, car park management system, water leakage detection system, waste water treatment plant, intruder alarm/ burglar alarm and maintenance management system were introduced newly as sub systems and equipment. The list of selection factors was finalised with the experts' opinions. Several new factors were newly added to the list while some factors were removed and some were combined where it was needed. Some new questions were added to the interview guideline regarding the tendering process and service and maintenance of the system while some questions were removed and adjusted based on experts' views.

The case studies were conducted among three organisations which have more than five years of experience in the fields of IBMS. In selected three cases, i.e. Cases A, B and C, the resource persons who involve in IBMS projects were project managers, project engineers, design engineers, commissioning engineers, technical executive and technicians. When discovering the demand for IBMSs in Sri Lanka, it shows that there is a huge demand in office buildings compared to banks, hotels and hospital buildings. This demand can be seen in both private and public sectors. As interviews revealed, there are lots of advantages of IBMS for building occupants. Basically IBMS optimise energy consumption. On the other side it maintains comfort level and increase efficiency in the building. And also, having IBMS building owners can reduce labour cost and ensure efficiency operation of sub systems and equipment.

This exploratory study evaluated and identified the major factors that should be considered in selecting sub systems and equipment for an IBMS. The findings have been presented in Table 1. Each sub system and equipment has a number of selection factors when deciding to integrate them to an IBMS. All the contractors are thoroughly concern about these selection factors when they design the IBMS. However, the selection factors identified through the research could be categorised into four main selection factors as higher efficiency, cost, improved safety and enhanced reliability. Among them, higher efficiency is perceived as the most important factor. Further, economical maintenance, improved safety and enhanced reliability are also considered significant.

In ensuring the overall efficiency of the IBMS, the work efficiency of each and every component is important. Further, the IBMS operator should be able to control and monitor sub systems and equipment during the operation and therefore, controlling and monitoring features are also considered when designing an IBMS. By measuring the working hours of sub systems and equipment building owners are comfortable to prepare maintenance schedules. Time scheduling feature assist in improving energy saving. Energy saving is a one of benefits of IBMS and therefore selected sub systems and equipment should optimise the energy consumption. Therefore, energy efficiency is also a factor which is considered in selecting systems and subsystems for the IBMS.

Sub systems and equipment can also be integrated with other systems to further optimise building comfort, safety and efficiency. For an example, pumps integrate with chillers, fire alarms integrate with AHUs and lifts, cooling towers integrate with chillers etc. Therefore, the ability of the sub systems and equipment to be integrated with others is also an important consideration. In a case of changing present status or an emergency the IBMS should be capable of make alarms and get immediate response. Moreover, for a building public announcement are very essential, especially in an emergency. And also current position of systems should be indicating in the IBMS. Further upgrade is important to all sub systems and equipment for the better operation of the building. Therefore, immediate response, indicate alarms public announcement, current position and further upgrade are also selection factors of sub systems and equipment. Initial cost and operating and maintenance costs are regarded as the two most crucial selection factors in selection of sub systems and equipment.

Table 1: System and Equipment Selection Factors of IBMS

System/ Equipment	Selection Factor																												
	Higher Efficiency	Work efficiency	Controllability	Monitoring ability	Preventive maintenance scheme	Time Scheduling feature	Energy efficiency	Interconnect with other sub systems	Response time	Indicate alarms	Public announcement	Possibility for further purgation	Indication of current position	**Cost**	Initial costs	Operating and maintenance costs	**Improved Safety**	Water leakage detection	Fire detection and fighting	Provision of safety and security	**Enhanced Reliability**	Productivity	Occupancy comfort	Indoor air quality	Control light level	Control temperature	Fuel consumption	Water consumption	Area under power supply
Chiller Plant		●	●	●	●	●	●	●	●	●		●			●	●						●	●			●			
Air Handling Unit		●	●	●	●	●	●	●	●	●		●			●	●						●	●	●		●			
Exhaust Fans		●	●	●		●			●	●		●			●	●							●	●					
Cooling Towers		●	●	●		●	●	●	●	●		●			●	●						●	●			●			
Pumps		●	●	●		●	●	●	●	●		●			●	●													
VRV System		●	●	●	●	●	●		●	●		●			●	●						●	●	●		●			
Fan Coil Unit		●	●	●	●	●	●	●	●	●		●			●	●						●	●	●		●			
VAV System		●	●	●	●	●	●		●	●		●			●	●						●	●	●		●			
Split Unit		●	●	●	●	●	●					●			●	●						●	●	●		●			
Generators		●		●	●	●		●		●		●			●	●						●	●				●		
Boiler		●		●	●	●				●		●			●	●				●							●		
Lighting		●	●	●		●	●					●			●	●						●	●		●				
Lifts and Escalators		●		●				●		●		●	●		●	●				●			●						
Fire Alarm				●				●	●	●	●	●			●	●			●	●									
Access Control		●		●						●		●			●	●				●			●						

System/ Equipment	**Selection Factor**																												
	Higher Efficiency	Work efficiency	Controllability	Monitoring ability	Preventive maintenance scheme	Time Scheduling feature	Energy efficiency	Interconnect with other sub systems	Response time	Indicate alarms	Public announcement	Possibility for further purgation	Indication of current position	**Cost**	Initial costs	Operating and maintenance costs	**Improved Safety**	Water leakage detection	Fire detection and fighting	Provision of safety and security	**Enhanced Reliability**	Productivity	Occupancy comfort	Indoor air quality	Control light level	Control temperature	Fuel consumption	Water consumption	Area under power supply
CCTV				●								●			●	●				●									
Car Park Management				●						●		●			●	●				●									
Water Management System		●		●						●		●			●	●		●					●					●	
Water Leakage Detection System				●						●		●			●	●		●		●									
Waste Water Treatment Plant		●		●						●		●			●	●												●	
Public Address System											●	●			●	●													
PABX System		●		●								●			●	●													
Intruder Alarms/ Burglar Alarm				●						●		●			●	●													
UPS		●		●		●				●		●			●	●				●									
Maintenance Management System		●		●				●		●		●			●	●						●	●						
Electrical Distribution System		●		●		●		●	●	●		●			●	●				●									●

When it comes to cost factor, initial cost and long-term expenses are the major concern of many building owners and decision makers. Selected sub systems and equipment of an IBMS such as leak detection and fire alarm systems provide safety and security for building owners and occupants. Therefore, security features are also considered in selecting components of IBMS. The high rank of occupancy comfort in sub systems and equipment implied a strong need for the provision of a comfortable and productive working environment to occupants. Selecting some sub systems and equipment for integration, it increases productivity and indoor air quality. Controlling of lighting level and temperature are other factors for selection of IBMS. Fuel consumption and water consumption is essential factors to consider when selection of sub systems and equipment.

7. CONCLUSIONS

A modern building contains various technical services in addition to HVAC, such as lighting, lift control, security and access control, CCTV, as well as the information technology network necessary for the user's business operation. Therefore, the management of facilities has become a complex task involving multitudes of disciplines. The role of the facilities manager is to provide a responsive and supportive environment in order to achieve the business success. A cost effective facilities management becomes possible when IBMSs are properly operated. The IBMS refers to a system where components may communicate with each other and generally implies some form of central supervisor, which permits monitoring and control of the building from a single point. When properly integrated in to a facility, IBMS can effectively optimise energy consumption, monitor and control of comfort conditions, enhance environmental quality, provide critical alarms and remedial actions, monitor performance and safety of assets and provide security solutions. Though IBMS is a relatively new concept for Sri Lankan industry, an increased application of IBMS could be seen in recent years and nowadays in Sri Lanka some of organisations provide more intelligent approach to the facility management, safety and energy control in IBMS. Therefore the knowledge on selection, design operational and maintenance aspects of IBMS is essential to a facilities manager. This research basically addressed the selection factors of the systems and equipment which are integrated with an IBMS. According to the research findings, various factors are considered when selecting sub systems and equipment to integrate with the IBMS. They can be categorised into four major selection factors as 'higher efficiency', 'cost', 'improved safety' and 'enhanced reliability'. Among them, efficiency is the as most significant important factor that should be given careful attention. The mangers of facilities should gain a comprehensive knowledge on the tools and techniques and well as criteria that should be taken into account in considering above selection factors and making the appropriate selection decisions.

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ESTABLISHING A POSITIVE SAFETY CULTURE IN RUBBER MANUFACTURING SECTOR: HUMAN FACTORS

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ABSTRACT

Safety and health in the rubber products manufacturing sector has been a neglected subject, though this sector is still a major foreign exchange contributor to the national economy in Sri Lanka, with significant contribution of Rs 72.3 billion in 2008. The rubber industry in the Sri Lanka employs many thousands of people and as it is a heavy industry, it poses a number of safety and health risks to workers employed in that sector. Occupational safety and health concerns in rubber manufacturing facilities have always been and continue to be of the utmost importance. Often the impact of serious workplace injuries overshadows the damage associated with illnesses which may be linked to workplace exposures. Thus, establishing of a positive safety culture is most critical in rubber manufacturing environments with a high risk of health and safety concerns. The cause analysis for failings related to safety culture in rubber manufacturing sector are varied and far reaching; with each issue coming into play at one critical point in time. However, these weaknesses include human and other factors such organisational, systems and processes etc. where majority of failures come under the category of human factors. Thus, understanding of these human aspects is crucial to establish and nurturing a safety culture that suits the organisation and the individuals within it. This paper therefore aims to investigate human factors which contribute towards establishing a positive safety culture in rubber manufacturing sector.

A comprehensive literature review and preliminary study were used as the research methodology for this paper. Key words; safety culture, definitions of safety culture, components of safety culture and way to establishing a good safety culture in rubber manufacturing sector were used to search the literature. Further, semi structured interviews were carried out with the industrial experts who are in charge of the concerned areas and with few shop floor level workers who are directly involved in production process. Research findings illustrated that yet, like in any other employment sector, workers in the rubber industry run an equal if not higher risk of being injured as a result of the type of work they do. Due to management and worker ignorance and rubber products manufacturing chemicals and bad work practices in some factories, serious hazards have been created and many accidents have occurred. Research findings illustrated that establishing a positive safety culture is about more than removing hazards and institutionalising safety procedures. It is about working with people of the organisation to change their attitudes, behaviours and thoughts, and improve their situational awareness. Research findings further illustrated that two key aspects under human factors to be considered when developing a safety culture in this sector namely; Psychological aspects and Behavioural aspects. These two aspects are inter-related where if something happens in one aspect it will influence the other aspect. Thus, each organisation needs to consider these aspects in establishing a positive safety culture that suits the organisation and the individuals within it. The finding of this research will be a guideline to propose a better working condition so that the safety culture can be created.

Keywords: *Human Factors; Rubber Manufacturing Sector; Safety Culture.*

1. INTRODUCTION

A safety culture is so much more than the "Safety First" sign hanging over the entrance door. Many industries around the world are showing an increasing interest in the concept of 'safety culture' as a means of reducing the potential for large scale disasters and accidents with routing tasks as disasters and accidents and their consequences continue to be a major public safety concern (Sukadarin *et al*., 2012). Besides, the Occupational Safety and Health Act (OSHA) (1994 cited in Hughes and Ferrett, 2013)

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stated that the self-regulation concept was promoted based on the primary responsibility of ensuring safety, health and welfare of all persons at all places of work. Therefore, an introduction of positive safety culture can be seen as a systematic solution towards the establishment of zero accidents in the workplace. Since manufacturing sector accounts for the second largest number of major injuries when compared with services (HSE United Kingdom Government estimate, 2007 cited in Crime Risk and Incident Management e-Service, 2008; Halim, Said and Said, 2012; Madugamuwa, 2012), establishing and strengthening a positive safety culture in manufacturing sector is important and it creates an atmosphere in which employees are aware of the risk in their workplace, continually on guard against them, and avoid taking any unsafe actions. This is crucial in rubber manufacturing sector because it as a heavy industry, it poses a number of safety and health risks to workers employed in that sector. Establishing a positive safety culture is affected by many factors such as human, organisational, systems and processes, etc. Accordingly, this paper aims to investigate only human factors which contribute to develop a positive safety culture in the rubber manufacturing sector.

2. SAFETY CULTURE

Safety culture is an abstract concept, giving researchers a large degree of freedom on how they understand these concepts and put them into practice (Havold, 2005). It is the ways in which safety is managed in the workplace, and often reflects the attitudes, beliefs, perceptions and values that employees share in relation to safety (Cox and Cox, 1991). Moreover, safety culture is just one of many within an overall organisational culture. With this context, following sub section explores the relevant literature in the research arena where major focus is given to two areas; Organisational culture and safety culture and safety culture in rubber manufacturing sector.

2.1. ORGANISATIONAL CULTURE AND SAFETY CULTURE

A positive safety culture should be developed within the framework of an organisational culture to ensure organisational consistency within safety culture programs (Clarke, 1999). Before continuing with a safety culture literature review, it is necessary to understand what organisational culture is in a broader context. Organisational culture comes from the external environment and the integration of an internal framework (Schein, 1990). Organisational culture is defined in many ways in literature. Organisational culture encompasses the central beliefs, values and basic assumptions that are shared by members of an organisation (Schein, 1990; Denison, 1996) and is often defined as “the way we do things around here” (Gludenmund, 2010, p.21). Part of that culture in hazardous industries relates to safety, which was defined by Reason (2000) as the ability of individuals or organisations to deal with risks and hazards so as to avoid damage or losses and yet still achieve their goals. The beliefs and values that refer specifically to safety and health form the subset of organisational culture referred to as safety culture (Clarke, 1999).

Safety culture, like organisational culture, does not have a universal definition. The concept of Safety Culture came into international usage following a report by the International Atomic Energy Agency (IAEA) in 1991, after the Chernobyl nuclear disaster in 1986 (Flin *et al*., 2000). The investigation report by the International Nuclear Safety Advisory Group (INSAG) of the International Atomic Energy Agency (IAEA) identified that poor safety culture as one of the contributing factors to this worst nuclear power plant accident in history (INSAG, 1986 cited in Europian Agency for Safety and Health at Work, 2010) and which led to safety culture being defined as an organisational atmosphere where safety and health is understood to be, and is accepted as, the number one priority. From then on the concept of safety culture has been used more and more in safety research, particularly in industries which have high potential for health and safety issues.

2.1.1. DEFINING SAFETY CULTURE

A safety culture generally refers to the extent to which very individual and every group of the organisation is aware of the risks and unknown hazards induced by its activities; is continuously behaving so as to preserve and enhance safety; is willing and able to adapt itself when facing safety issues; is willing to communicate safety issues; and consistently evaluates safety related behaviour. The term is loosely used to describe the corporate atmosphere or culture in which safety is understood to be, and is accepted as, the number one priority (Cullen, 1990). Numerous definitions of safety culture exist in the literature, and examples of selected definitions are shown in Table 1.

Table 1: Definitions of Safety Culture

Reference	**Definition**
Cox and Cox (1991)	Safety culture is the ways in which safety is managed in the workplace, and often reflects the attitudes, beliefs, perceptions and values that employees share in relation to safety
Kennedy and Kirwan (1998)	An abstract concept, which is underpinned by the amalgamation of individual and group perceptions, thought processes, feelings and behaviours, which in turn gives rise to the particular way of doing things in the organisation. It is a sub-element of the overall organisational culture
Hale (2000)	Refers to the attitudes, beliefs and perceptions shared by natural groups as defining norms and values, which determine how they act and react in relation to risks and risk control systems
Glendon and Stanton (2000)	Comprises attitudes, behaviours, norms and values, personal responsibilities as well as human resources features such as training and development
Guldenmund (2000)	Aspects of the organisational culture which will impact on attitudes and behaviour related to increasing or decreasing risk
Cooper (2000)	the product of multiple goal-directed interactions between people (psychological), jobs (behavioural) and the organisation (situational); while safety culture is 'that observable degree of effort by which all organisational members directs their attention and actions toward improving safety on a daily basis
Mohamed (2003)	A sub facet of organisational culture, which affects workers' attitudes and behaviour in relation to an organisation's on-going safety performance
Richter and Koch (2004)	Shared and learned meanings, experiences and interpretations of work and safety - expressed partially symbolically – which guide people's actions towards risk, accidents and prevention
Fang *et al*. (2006)	A set of prevailing indicators, beliefs and values that the organisation owns in safety
National Institute for Occupational Safety and Health (NIOSH) (2008)	Underlying organisational principles, norms, commitments and values related to the operation of safety and health, as well as its importance compared with other workplace goals.

Most of the definitions are relatively similar in the beliefs perspective, with each focusing, to varying degrees, on the way people think and behave in relation to safety. The definitions (refer Table 1) adopted by Hale (2000), Glendon and Stanton (2000) and Cooper (2000) are the most practical, as they clearly outline the contents of safety culture. Lee and Harrison (2000) reveal that basically, any safety management system is a social system, wholly reliant upon the employees who operate it. Its success depends on three things: its scope; whether employees have knowledge about it; and whether they are committed to making it work. The concept of safety culture has evolved as a way of formulating and addressing this new focus. In line with this, the Advisory Committee on the Safety of Nuclear Installations (ACSNI, 1993) provides the definition that the safety culture of an organisation is the product of individual and group values, attitudes perceptions, competencies and patterns of behaviour that determine the commitment to and the style and proficiency of an organisation's health and safety management.

The latest definition of safety culture is proposed by Fang *et al*. (2006): a set of prevailing indicators, beliefs and that the organisation owns in safety. In practice, establishing a safety culture is due to the goal directed of various organisational characteristics by considering the impact upon safety management practices. The specific principles are reductions in number of accidents and incidents, ensuring that safety issues receive appropriate attention, ensuring that organisational members share the same ideas and beliefs about risks, accidents, and illness related to health and, determining the style and proficiency of an organisation's health and safety programs. Companies are being encouraged to adopt a positive organisational safety culture in order to safeguard their operations against accidents and it is accepted as the number one priority (Clarke, 2003; Sukadarin *et al*., 2012). In hazardous industries, like aviation, nuclear power, rubber manufacturing and fuel transportation this makes sense. The next section reviews the safety culture in rubber manufacturing industry.

2.2. SAFETY CULTURE IN RUBBER MANUFACTURING SECTOR

Safety and health in the rubber products manufacturing sector has been a neglected subject, though this sector is still a major foreign exchange contributor to the national economy in Sri Lanka, with significant contribution of Rs 72.3 billion in 2008 (Yogaratnam, 2010). Occupational safety and health concerns in rubber manufacturing facilities have always been and continue to be of the utmost importance. Often the impact of serious workplace injuries overshadows the damage associated with illnesses which may be linked to workplace exposures. Yet, like in any other employment sector, workers in the rubber industry run an equal if not higher risk of being injured as a result of the type of work they do. Many mechanical and chemical hazards exist in the rubber manufacturing organisations, where a large number of unskilled and semi-skilled workers are employed. Further, due to management and worker ignorance and rubber products manufacturing chemicals and bad work practices in some factories, serious hazards have been created and many accidents have occurred (Vecchio-Sudus and Griffiths, 2004; Yogaratnam, 2010).

Generally, the production of rubber items involves subjecting heterogeneous mixtures of hundreds of chemicals to heat, pressure, and catalytic action during a variety of manufacturing processes. As a result, the work environment may be contaminated with dusts, gases, vapors, fumes, and chemical byproducts. Workers may be exposed to these hazards through inhalation and skin absorption during rubber processing and product manufacturing. Physical hazards such as noise, repetitive motion, and lifting may also be present (Centre for Disease Control and Prevention, 1993; Thompsons Solicitors, 2013). Thus, establishing of the safety culture is most critical in rubber manufacturing environments with a high risk of safety and health concerns and it can be an effective tool for improving safety and addressing safety related issues within the above said sector.

As an overall, the cause analysis for failings related to safety culture in rubber manufacturing sector are varied and far reaching; with each issue coming into play at one critical point in time. However, these weaknesses include human and other factors which festering in the organisation, reflecting the underlying safety culture, are often also contributory factors (Gunasekara and De Alwis, 2008; Ahmed and Hossain, 2009; GL Noble Denton , 2013).Weaknesses in safety culture related to; Poor management commitment to safety, Prioritising cost-cutting and production above safety, Complacency about risks, Staffing issues and excessive workload, Inappropriate rewards and incentives for reporting incident, Inadequate training for emergencies, Leaders inconsistently modeling safety behaviours, Absence of learning from past incidents, Fear of speaking up by staff, Poor competency of managers in risk/hazard management, Safety critical tasks not performed, Organisational change poorly managed and Inadequate communication etc. (GL Noble Denton , 2013). Most of the weaknesses mentioned in above are related with 'Human factors'. Thus, having better understanding on human factors on this perspective will be an effective tool in addressing those failures and establishing a positive safety culture in rubber manufacturing environment will ensure the long term business continuity together with protection of employees, customers and properties.

3. RESEARCH METHOD

The study was structured in several steps. A background study was carried out on a broader perspective with the purpose of getting familiarised with the subject areas of the research study while holding the focus on research problem. The background study took the attention of journal articles, online journals, e-books, web sites, electronic library data base and other publications. Based on knowledge gained, an interview guideline was developed, investigating the research question of what are the factors which contribute to develop a positive safety culture in rubber manufacturing sector. The interview guideline consisted of five stages as Introduction to the research, Importance of safety culture for rubber manufacturing industry, Involvement of individual and behavioural (human) and management for developing a positive safety culture in rubber manufacturing sector. Data collected from respondents whom are in charge of the concerned areas of rubber manufacturing sector and from few shop floor level employees who are directly engaged with production process (refer Table 2). The industrial experts were selected based on number of years of experience in the respective industries. Semi structured interviews were carried out with them to identify factors which contribute towards establishing a positive safety culture in manufacturing sector.

Table 2: Interview Profile

Selected Respondents	Designation	No. of Years of Experience in the Respective Industries
Industrial Experts (IE)		
IE1	Senior Manager - Environmental Health and Safety (EHS)	12
IE2	Manufacturing Manager	15
IE3	Senior Manager - Compliance and EHS Systems	10
IE4	Senior Compliance Office	8
IE5	Senior Safety Engineer	11
Shop Floor Level Employees		
Few Machine Operators		7 - 12

4. RESEARCH FINDINGS AND DISCUSSION

It is not possible to graft a general safety culture into rubber manufacturing organisation, as each organisation is unique with their nature of business, processes, systems etc. and the best safety systems in the world will fail without a supportive culture. Safety performance of the human is strongly linked to organisation's safety culture. Safety culture can be divided into three aspects as psychological, behavioural and situational (Cooper, 2000). Psychological and behavioural aspects directly link with human factors (refer Figure 1). Situational aspects will not be discussed in this study as it mainly discuss about the 'what the organisations has' which includes policies, procedures, regulations, organisational structures and management system.

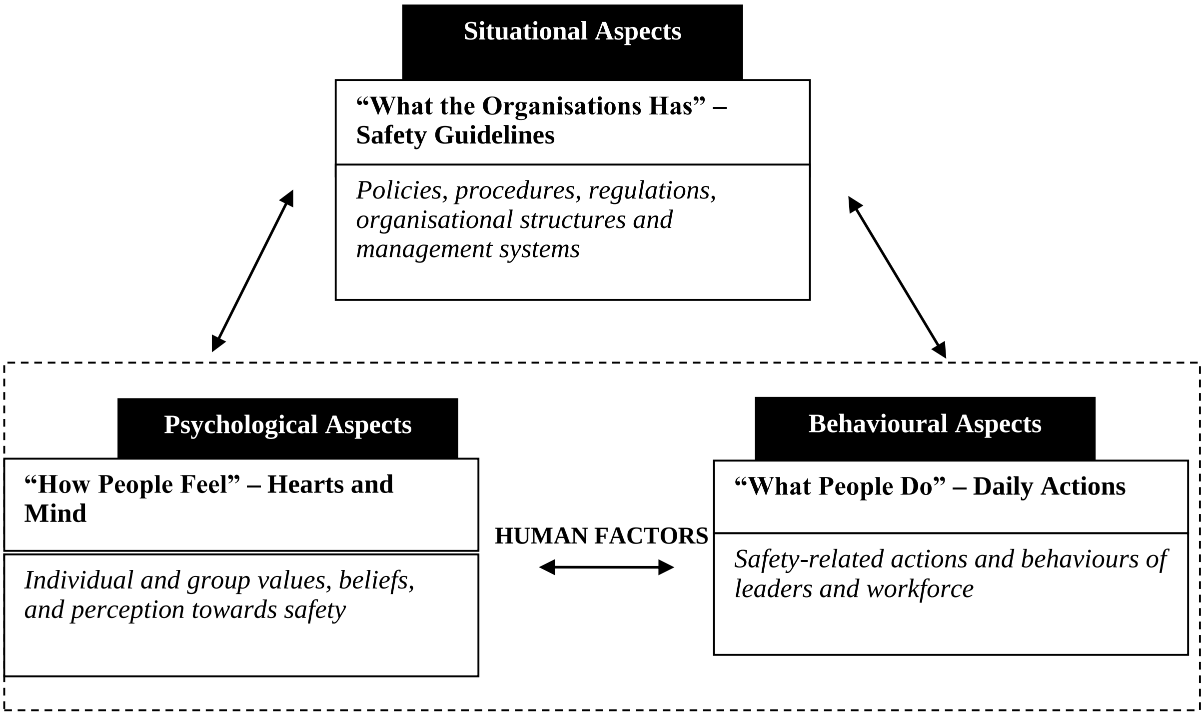

Figure 1: Elements of Safety Culture
Source: Adapted from Cooper (2000)

These three aspects are inter-related where if something happens in one aspect it will influence the other two. The next two sub sections discuss about the psychological and behavioural aspects.

4.1. PSYCHOLOGICAL ASPECTS

The psychological aspects state how employees think and feel about safety and it is usually about winning over people's heart and minds. Many industrial experts and results from the preliminary study revealed that the key factors such as individual and group values, beliefs and perception and attitudes towards safety significantly contribute in establishing a safety atmosphere in rubber manufacturing environment. This is more alike with literature where many researchers stated that safety culture often reflects the attitudes, beliefs, perceptions and values that employees share in relation to safety. For an example, the definitions adapted by Mohamed (2003) clearly indicate that safety culture affects workers' attitudes and behaviour in relation to an organisation's on-going safety performance.

Attitudes, both personal and organisational, affect development of a safety culture in a workplace. According to Lin and Mills (2001) and Sukadarin *et al*., (2012), safety is something found to be the first item to face cost cutting as the employers who often believe that implementing a safety system will cost more. In addition, managerial focus tend to concentrate on production "at cost" and safety does not help production therefore it suffers when expenses runs over budget. This was the same idea of most of the shop floor level workers who are working in rubber manufacturing organisations as machine operators. Some of the workers mentioned that *"profit before safety where productivity always came before safety, as safety was viewed as a cost, not an investment."* However, the industrial experts (IE1, IE2, IE3 and IE5) who are in charge of the concerned areas disagreed with this fact and they stated that "*we are providing the safety for them. But some of the workers still neglect safety guidelines provided with them. For an example, the wearing of protective clothing and the use of safety equipment is crucial in reducing the effects of accidents on production area. It is often the case that safety equipment is provided, but some employees are reluctant, or neglect, to wear it.* He further mentioned that some workers still not fully understand the purpose of conducting accident investigations. They assumed that, it is made to find who is to be blame in any accident or incident rather than to focus on reoccurrence of accident or incident prevention. The misunderstanding between both parties shows the conflict of attitudes towards safety and at the same time it highlights importance of positive attitudes, individual and group values, beliefs and perception towards safety in terms of establishing a positive safety culture in rubber manufacturing environment. Hence, the good understanding and strong relationship between both management and employees help to feel them that safety is everyone's responsibility in order to create the safety culture in the organisation. The vision for the organisation is that the workplace will be free of incidents/injuries and safety and health is integrated into every aspect of the work process. This attitude should be evident throughout the organisation from the managing director through to the newest and most inexperienced member of the workforce.

However, workers tend to be more careful in what they do when their social responsibilities are higher. Industrial experts did clarify that those workers who are married and have more dependences in their families tend to follow safety instructions and guidelines onsite than others. The study by Hinze (1997) and Choudhrry *et al*. (2009) found that the married workers exhibited more positive attitudes towards safety. Workers' mental stability is crucial factor to be concerned with the complexity of manufacturing processes carried out and especially when workers operate machines. Therefore, counselling has become a key factor of safety culture in rubber manufacturing environment which has not disused in literature yet. According the Hale (2000), safety culture refers to the attitudes, beliefs and perceptions shared by natural groups as defining norms and values, which 'determine how they act and react in relation to risks and risk control systems'. As per this definition, safety culture is not about psychological aspects and these aspects influence people to behave in relation to safety. The behavioural aspects comprise of employees' everyday actions in regards to safety and next section discuss about the behavioural aspects.

4.2. BEHAVIOURAL ASPECTS

Behavioural aspects dictate what employees do in regards to safety and it includes their day-today activities towards safety in their working environment. Many industrial experts believed that commitment at all levels as another important factor of safety culture. They further mentioned that organisation should adopt safety and health as a core value and actively cares for the workforce. However, literature findings show that the commitment from the managerial level in order to create and promote safety culture is still weak. Putting more priority in making profit instead of workers, safety is not acceptable at all (Sukadarin *et al*., 2012). The industrial experts who are in charge of the concerned areas disagreed with this fact (refer Section 4.1). As explained in Section 4.1, some workers are reluctant to wear safety clothing and safety equipments during the working time. Consequently, the provision of safety equipment alone does not improve safety, there also needs to be a corporate culture that encourages its use. At this level, management commitment plays a significant role and also it is required to enforce the wearing of safety equipment. Not only commitment from management but also commitment at all levels is another important human factor in creating a safety culture. Since health and safety concerns in rubber manufacturing facilities have always been and continue to be of the utmost importance, commitment at all level is required to establish a positive safety culture.

IE5 (Senior Safety Engineer) highlighted that strong leadership is very much essential to drive the safety culture within manufacturing environment. Ineffective leadership, where blinkered leadership and the prevailing corporate culture prevented the recognition of risk and opportunities leading to wrong safety decisions being made at the wrong time and for the wrong reasons. Experts have observed that the workers who are older in age more cautious about work safety than youngsters in the industry and they tend to behave more safely for their own protection. A recent study by Sukadarin *et al*. (2012) stated that workmate's influence, safety knowledge and safety behaviour are also crucial factors in grafting the safety culture onto manufacturing sector. He further indicated that, most of the workers in the manufacturing sector have the knowledge to work safely for the example, they know about hazard in the specific job, the control measure that need to be taken in avoiding any accident to happen and any necessary information regarding to their job task. The definition (refer Table 1) adopted by Glendon and Stanton (2000) stated that safety culture comprises with attitudes, behaviours, norms and values, personal responsibilities as well as human resources features such as training and development. Considering the effective safety training and development, IE1 (Senior Manager – EHS) stated that *"It is essential to provide proper training and safety information for everyone. Workers who are provided with regular information about safety and health at work are more likely to be mindful of safety and health issues and the ways in which their actions can affect themselves and others*". Further, Davies and Tomasin (1999) suggest that effective training in workplace is one means by which safety can be improved and company management must be active in order to reduce the number of injuries and fatalities. Nishgaki (1994) and Garza (1988) both recommended that educating and training of workers about all aspects of work safety and giving them the skill to look after themselves is the right thing to do. However, Preliminary findings further revealed that posters, warning signs and policies are not enough and safety and health discussions and information distribution should be built into all aspects of the work process from board meetings to individual interactions. People who are properly trained in their jobs and are aware of the hazards associated with the role they, or those they supervise, perform are less likely to suffer or cause injury. Therefore, training can take a variety of forms and should be ongoing throughout an individual's time with the organisation. Employee participation is another important human factor which helpful in fostering a positive safety culture. Empirical data further revealed that employee participation includes EHS committee meetings, Near miss promotional campaigns, Rewarding and Poster competitions, Street drama, and Quiz competitions as way of communicating the importance of safety culture to the organisation.

Fleming and Lardner (1999) have discovered the human factors contribute to 80-90% of all industrial accidents. Thus, each organisation needs to consider all of these aspects in developing and strengthening the safety culture that suits the organisation and the individuals within it. Figure 2 depicts the all the human factors including psychological and behavioural factors discussed in above.

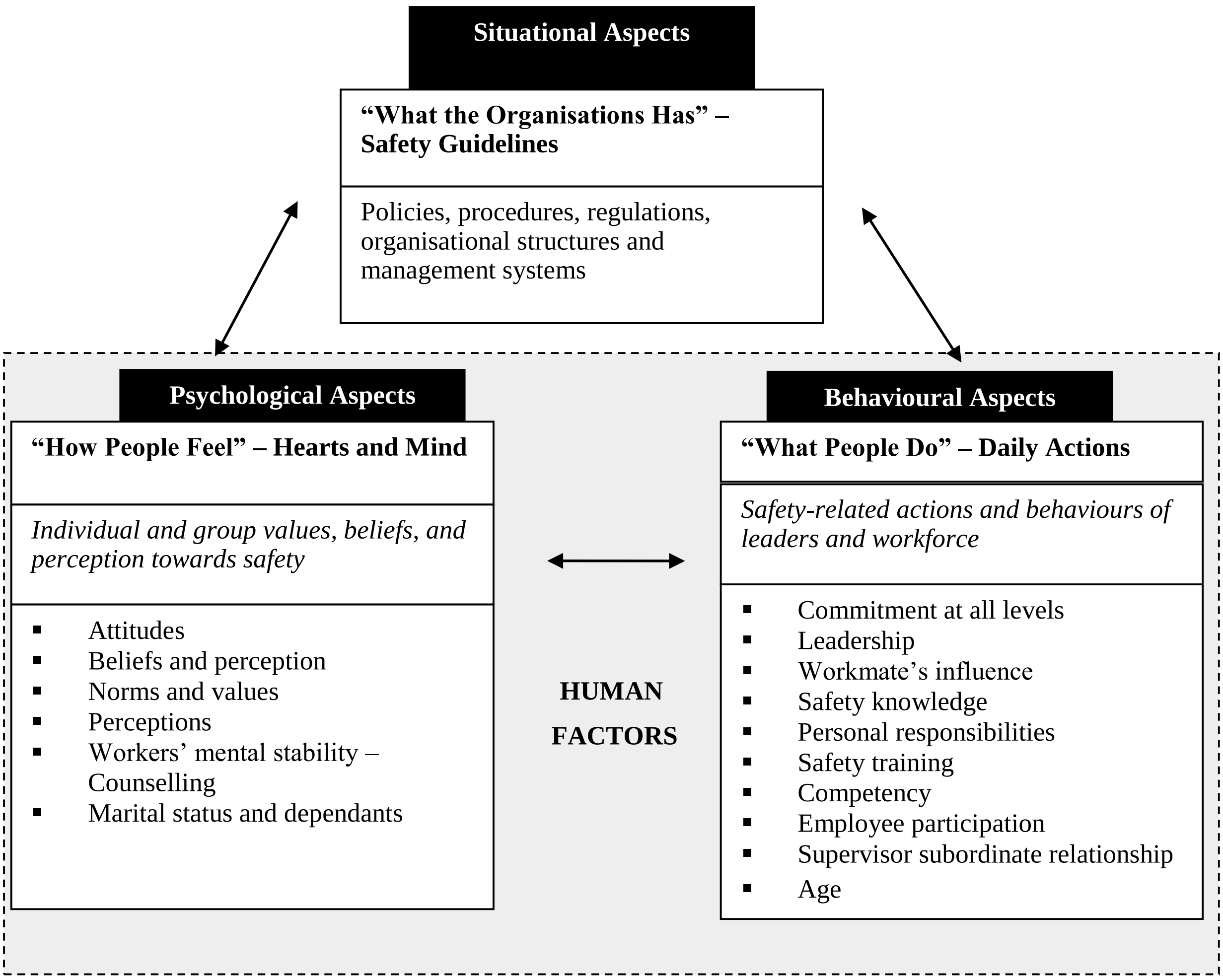

Figure 2: Human Factors Contributing Towards Establishing a Positive Safety Culture in Rubber Manufacturing Sector

5. CONCLUSIONS

This paper reviewed the existing literature and preliminary findings to investigate human factors which contribute towards establishing a positive safety culture in rubber manufacturing sector. Since health and safety concerns in rubber manufacturing environment have always been and continue to be of the utmost importance, creating a positive safety culture is very important. Research findings revealed that creating a strong safety culture is about more than removing hazards and institutionalising safety procedures. It's about working with people of the organisation to change their attitudes, behaviours and thoughts, and improve their situational awareness within the dynamics of today's world. Also, literature findings disclosed that safety culture is mainly focus on the way people think and behave. Therefore, this highlights the importance of human factors in establishing a positive culture. Human factors include both psychological and behavioural aspects. These two aspects are inter-related where if something happens in one aspect it will influence the other aspect. Each organisation needs to consider all of these aspects in developing and strengthening the safety culture that suits the organisation and the individuals within it. Moreover, everybody needs to understand that safety is everyone's responsibility in order to create the safety culture in the organisation.

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ESTABLISHING AN INTEGRATED MODEL FOR MEASURING THE SITE SAFETY PERFORMANCE OF CONSTRUCTION PROJECTS: LITERATURE REVIEW AND FUTURE RESEARCH AGENDA

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ABSTRACT

Safety issues have always been a major problem besetting the construction industry in many countries because of the hazardous nature and complexity of the work. Previous government statistics have manifested that the highest number of accidents and fatalities are found in the construction industry when compared with other major industry sectors throughout the world. In Hong Kong, the construction industry is also regarded as high-risk. There are different construction site safety assessment methods proposed by some researchers. However, there is a lack of holistic assessment model for site safety performance of construction projects. In this study, the essential factors needed for safety assessment and their associated sub-factors are those which affect the level of safety performance. This paper aims to put forward a research framework for developing a holistic site safety assessment model for new construction projects in Hong Kong using the Delphi survey technique. It will be a multi-factor model where the core factors are expressed both in broad terms and as finer, more detailed, sub-factors. Successful development of the site safety assessment model can then enable the setting up of a benchmarking tool for measuring and comparing the overall safety standards of the various construction projects within an organisation, between organisations and within the construction industry as a whole leading to an improved site safety culture.

Keywords: *Factors Affecting Site Safety; Hong Kong; Research Framework; Safety Performance; Site Safety Assessment Model.*

1. INTRODUCTION

Safety on construction sites in Hong Kong remains a prime concern even though significant improvements have been made in 2003-2012 (Labour Department, 2013). The high-risk construction industry still records the highest accident rate and number of fatalities amongst the various major industry sectors. As compared with 2011, the number of construction accidents recorded in 2012 increased from 3,112 to 3,160 by 1.5% (Labour Department, 2013). The implementation of a structured, holistic site safety assessment is thus regarded as good construction safety management practice for accident prevention and mitigation.

Despite the fact that different construction safety evaluation methods have been proposed worldwide, a more holistic site safety assessment model which takes into account all the essential factors and their associated sub-factors pertinent to safety performance has yet to be realised (Sawacha *et al*., 1999). There exist no comprehensive standard assessment tools which take account of all the essential factors and their underlying sub-factors which can be applied to measure an overall safety standard of a construction site. A site with a higher safety standard is more likely to achieve better safety performance. Therefore, a strong urgent need exists to formulate a holistic site safety assessment model now with a view to uplifting current construction safety performance as a whole in Hong Kong.

An effective safety assessment protocol can substantially improve site safety because it can not only identify in advance some under-performing areas and major hazards for remedial action at an early stage but also help management to devise ways of making operations safer and creating a safer working environment (Anton, 1989; Abdelhamid and Everett, 2000; Rowlinson, 2003). Systematic research is

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also needed in order to understand how to build a model which will provide a single overall measure of safety assessment for any particular project, a useful tool as part of a site safety assessment system. Therefore, an integrated site safety assessment model is an essential tool for measuring, evaluating, monitoring and raising the current safety performance of construction projects. With the purpose of developing such an assessment model, a basket of consolidated key factors and their corresponding sub-factors contributing to safety performance as a whole are required which, however, are at present lacking within the construction industry.

2. RESEARCH AIM AND OBJECTIVES

This paper purports to illustrate a research paradigm for establishing a holistic, objective and reliable site safety assessment model for construction projects in Hong Kong. And two specific research objectives were set out as follows.

Objective 1: To identify a list of essential factors and their associated sub-factors which affect the safety performance of a construction project.

Objective 2: To determine a series of weightings for these factors and sub-factors in assessing an overall site safety standard.

3. ESSENTIAL FACTORS AFFECTING CONSTRUCTION SAFETY PERFORMANCE

Several research studies have led to the identification of those essential factors affecting the safety performance of construction projects. For instance, Jannadi (1996) explored the major factors affecting construction safety in the United Kingdom, i.e. safe working conditions, safety training, good safety habits, effective control of subcontractors, and close supervision on site workers. Jaselskis *et al*. (1996) provided excellent strategies for improving construction safety performance in the United States, including the number of safety inspections, dollars spent on safety programmes and percentage of time devoted to safety issues. Mohamed (1999) undertook a detailed empirical investigation into the relationship between the intensity of safety management commitment and the overall safety performance in the Australian construction industry.

Sawacha *et al*. (1999) studied seven groups of factors that can have an influence on the safety performance of construction sites in the United Kingdom, including historical, economical, psychological, technical, procedural, organisational, and environmental factors. Fang *et al*. (2004) identified the significant factors that affect safety management and then developed a safety assessment method for measuring the safety management performance of construction sites in Mainland China using factor analysis.

Tam *et al*. (2004) examined the status of safety management in the Mainland Chinese construction industry and determined the essential factors influencing site safety, i.e. poor safety awareness of leaders and managers, lack of safety training and resources, low labour skills level, insufficient enforcement of safety rules and safety equipment. Ng *et al*. (2005) established a comprehensive framework which takes into account the main factors and sub-factors pertinent to an organisation and its project for evaluating the safety management standards of the various construction contractors in Hong Kong.

Teo and Ling (2006) developed a model that safety auditors may use to assess the effectiveness of safety management systems implemented by construction firms in Singapore. Imriyas (2009) established an expert system for strategic control of accidents and insurers' risks for building projects in Singapore, and selected some key factors to be adopted in estimating a Project Safety Index (PSI).

Despite the above research studies, those identified key factors have not been linked together to provide an integrated single safety management indicator with the objective of comparing different site safety standards.

4. RESEARCH METHODOLOGY

The research process will comprise the following key stages: (1) literature review; (2) face-to-face structured interviews; (3) Delphi questionnaire survey; (4) data collection; (5) data analysis; (6)

development of a site safety assessment model; and (7) validation of the developed model. Figure 1 indicates the overall research framework for the proposed study for perusal.

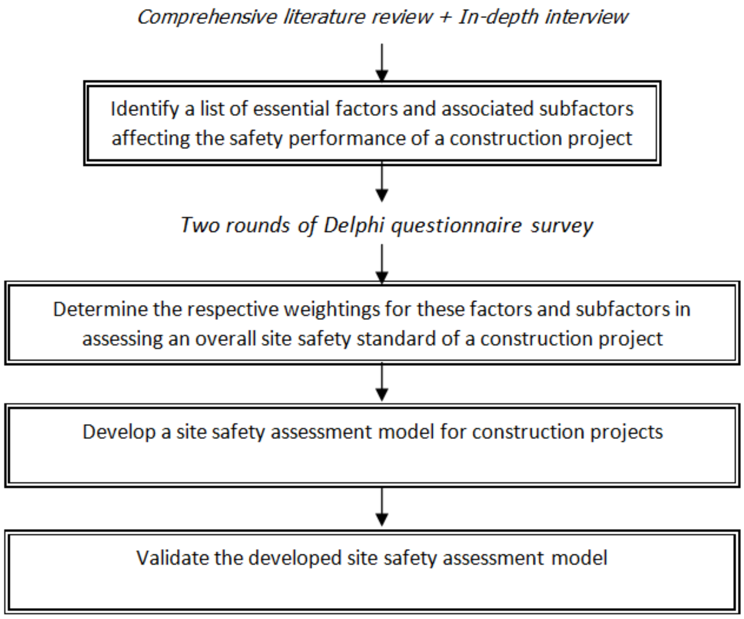

Figure 1: Flow of the Overall Research Framework

Objective 1: To identify a list of essential factors and their associated sub-factors which affect the safety performance of a construction project.

The study will begin with an extensive review of the literature on the essential factors contributing to safety performance and other site safety assessment systems and models for construction projects from all available sources. All previous relevant studies will be summarised so as to condense existing knowledge and experience on prevailing safety practices, safety regulations and safety management systems, safety performance assessment, and the principal causes of site accidents. The review will help develop the overall research framework, and help prepare appropriate templates for the in-depth structured interviews, and the Delphi questionnaire survey.

Typical core factors affecting the level of site safety performance may include: (1) complexity of project; (2) degree of safety supervision; (3) rate of labour turnover; (4) frequency of safety inspection; (5) control and management of subcontractors by main contractor; (6) frequency of legal conviction in safety; (7) experience of construction workers; (8) efforts on safety promotion; (9) frequency of safety audits or reviews; (10) frequency of reported accidents; (11) contribution of top management to safety; (12) extent of safety training and personal protection; (13) frequency of safety meeting; and (14) implementation of preventive and corrective safety measures (Chiu, 2009). Each of these 14 core factors will be further subdivided into underlying sub-factors to obtain more detailed understanding.

Through the literature review, an initial checklist of these essential safety factors and their associated sub-factors for a construction project will be placed within a systematic hierarchy of three levels: (1) the overall safety standard (at first level); (2) the core safety factors (at second level); and (3) the safety sub-factors (at third level) as indicated in Figure 2. Then a series of face-to-face in-depth interviews with relevant senior industrial practitioners (e.g. government officers, project managers, safety managers, safety officers, safety engineers, building engineers, building services engineers, safety consultants, safety academics, etc.) will be conducted to solicit their opinions and feedback on these core safety factors and sub-factors based on their abundant hands-on experience with site safety. Finally, a full list of the core factors and their associated sub-factors contributing to safety performance will be produced.

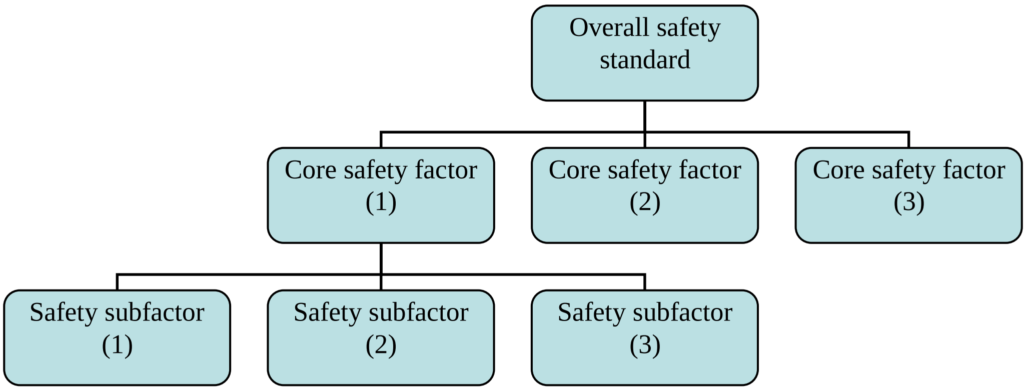

Figure 2: A Systematic Hierarchy of Essential Safety Factors and their Associated Sub-factors for a Construction Project

Objective 2: To determine a series of weightings for these factors and sub-factors in assessing an overall site safety standard.

After the literature review and interviews, two rounds of Delphi questionnaire survey will be launched as adapted by Lo (1999) and Yeung *et al*. (2007) in order to evaluate the relative importance (weightings) of the respective factors and sub-factors affecting project safety performance. The Delphi survey technique will be the primary analysis tool applied at this stage because a consensus needs to be reached. The Delphi survey method is a highly formalised method of communication designed to extract the maximum amount of unbiased information from a panel of experts (Chan *et al*., 2001; Yeung *et al*., 2007; Chan and Chan, 2012). It is generally conducted in several rounds interspersed with group opinions and information feedback in the form of relevant statistical data. Generally, the number of rounds ranges from 2 to 7 and the number of participants varies between 3 and 15 (Rowe and Wright, 1999; Adnan and Morledge, 2003). The desired outcome, by using an iterative forecasting procedure, is that on reaching the final round, the experts will have achieved unanimity on the issues put before them (Manoliadis *et al*., 2006). Therefore, the Delphi survey method is appropriate for identifying the set of the most important factors and sub-factors to be used in assessing site safety standards.

The selected panel of Delphi experts will include industrial practitioners equipped with extensive hands-on working experience in site safety assessment and prominent academics with demonstrated research experience in site safety. The Delphi experts will include government officers, project managers, safety managers, safety officers, safety engineers, building engineers, building services engineers, safety consultants, safety academics, and other allied construction professionals.

The first round of the Delphi questionnaire survey will be based on the identified list of core factors and sub-factors influencing safety performance in Stage 1. The target respondents will be invited to provide "importance" ratings to each of the identified safety factors and sub-factors based on a five-point Likert scale, ranging from 1 = least important; 2 = slightly important; 3 = important; 4 = very important and 5 = most important. A Likert scale will be adopted because the dimensions for measuring the importance of each safety factor or sub-factors should be unipolar, i.e. there are different degrees of the same attribute (Schwarz, 1996). When analysing the data, the focus must be on the opinions of the group rather than those of individuals. Therefore, the Kendall's concordance test measuring the consistency of the experts' responses over successive rounds of the Delphi questionnaire will be required. A statistical analysis will be performed on all survey questionnaires received in which the mean ratings for all the safety factors and sub-factors will be computed. Hence, a series of safety factors and sub-factors with their respective weightings will be derived based on the mean ratings advocated by the Delphi group of panel experts. The weighting for each safety factor and sub-factors will be calculated as their individual mean ratings divided by the total mean ratings of all the factors or sub-factors under consideration as computed using the following equation (Chow, 2005; Ng *et al*., 2005; Yeung *et al*., 2007; Eom and Paek, 2009; Chan *et al*., 2011; Chan and Chan, 2012):

$$W_{SF_a / SS_a} = \frac{M_{SF_a / SS_a}}{\sum_k M_{SF_k / SS_k}} \qquad \text{for a = 1} \qquad \text{(Eq: 01)}$$

Where, W_{SF_a / SS_a} represents the weighting of a particular safety factor (SF) / safety sub-factors (SS)

M_{SF_a / SS_a} represents the mean ratings of a particular SF / SS

$\sum_g M_{SF_k / SS_k}$ represents the summation of mean ratings of all the SF / SS

In Round 2 of the Delphi questionnaire survey, each participating Delphi expert will be given the consolidated results obtained from Round 1. The average ratings of the Delphi experts for all the safety factors and sub-factors, together with the Delphi expert's own ratings suggested in Round 1 will be provided. Each Delphi expert will then be requested to reconsider his/her own ratings to see if they would like to adjust their original judgements in the light of the mean scores of all the Delphi experts. By doing so, the most important weighted safety factors and sub-factors will be found out. It should be noted that the Delphi survey technique has been widely applied in many complex areas in which a consensus needs to be reached (e.g. Chan *et al*., 2001; Anatharajan and Anataraman, 1982; Saito and Sinha, 1991; Manoliadis *et al*., 2006; Yeung *et al*., 2007; Chan *et al*., 2011). Therefore, the application of the Delphi method is desirable because of the rather subjective nature of the opinions.

5. VALIDATION OF RESEARCH FINDINGS

Triangulation from multiple sources will be employed to reinforce the credibility of the findings obtained from the research data and subsequent analyses. Results derived from the in-depth interviews and the Delphi questionnaire survey will be cross-referenced to the published literature as well as with each other whenever appropriate. Appropriate workshop discussions with prominent industrial practitioners who have acquired extensive hands-on experience in dealing with various essential factors influencing the safety performance of new construction sites will be organised to generate relevant information and to supplement and/or confirm the outcomes of the analyses, and a set of possible recommendations for improving the developed site safety assessment model based in Hong Kong. A meeting will be scheduled via discussions and moderations to validate the research findings and explanations with practitioners involved in the study.

6. SIGNIFICANCE AND VALUE OF RESEARCH

According to the Occupational Safety and Health Statistics for 2012 published by the Labour Department (2013), 25.2% of the industrial accidents (3,160 out of 12,547) were in relation to the construction industry in Hong Kong. The safety record of the construction industry was poor and much worse than other major industries in Hong Kong (Wong *et al*., 2004). Although the Labour Department has promulgated several safety and health policies and regulations to avoid or mitigate the occurrence of accidents, the frequently reported cases of site accidents prove that their effectiveness is far from satisfactory, and the overall safety performance is still at a high level.

Site supervisory teams do not usually conduct a proper, holistic site safety assessment. Despite some research studies undertaken on safety management evaluation, those important individual factors identified have not been combined together to generate an integrated single measure of site safety for the objective comparison of different workplace safety standards. This undesirable situation may be attributed to the lack of an appropriate safety assessment mechanism that could be employed to evaluate the existing safety standards in town. To remedy this deficiency, this proposed study will investigate the subject and develop a holistic, objective and reliable site safety assessment model for use. Project managers, safety managers, safety officers, safety engineers, safety consultants and other related construction personnel will be assisted with such a model to objectively assess the overall safety standards of their individual projects, and to prioritise improvement measures for the under-performing areas.

A practical site safety assessment model can enable developing a benchmarking tool for measuring and comparing the overall safety standards of the different construction projects within an organisation, between organisations and within the construction industry. A composite overall site safety assessment score, which is representative of all the essential factors and their associated sub-factors, will be derived by the model to provide this single measure. The safety standards of different construction projects can then be evaluated and compared objectively on the same basis for benchmarking purposes. The overall safety assessment score can be monitored throughout the entire construction period for any one site and upon completion. The model will ultimately be developed as an online computerised system enabling industrial practitioners to easily and promptly measure and compare their overall safety standards in search of future safety excellence.

7. CONCLUSIONS

There exist many causes of accidents on construction sites, but key is the general lack of awareness of the nature of the various essential factors contributing to safety performance. Assessing safety performance simply by looking at the number of accidents or legal convictions alone has long been perceived as an inadequate measure or indicator for a particular construction site (Ng *et al.*, 2005). However, there is no comprehensive and systematic empirical research into this issue which takes into consideration all the essential factors and their underlying sub-factors available that influence the safety performance of construction projects as a whole, especially in Hong Kong. To improve the situation of short of an appropriate safety assessment mechanism in town, this proposed research aims to develop a holistic, objective and reliable site safety assessment model. The site safety assessment model will be made computerised to facilitate easy application. Although the research study will primarily focus on the prevailing situation in Hong Kong, the research methodology will be applicable to many other parts of the world. Indeed, it could form the basis for international comparisons of the extent to which the essential factors contributing to safety performance are identified, evaluated and guarded against.

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FACTORS AFFECTING CONSTRUCTION COSTS IN SRI LANKA

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ABSTRACT

This study identifies severe cost factors that define the construction project cost in order to reduce costs and cost overruns in public sector building projects. A comprehensive literature survey was followed by two rounds of Delphi surveys to extract a set of exclusive cost factors and their levels of importance with the participation of a panel of 30 experts. Severity index (to rank the cost factors according to the importance), correlation analysis (to check the agreement between the parties), cross tabulation (to identify the linear relationships between the collected data) and hypothesis testing (to prove the agreements between the parties and to check the confident levels) were used to analyse the data.

According to the research study findings, 44 cost defining factors were identified for the public sector building projects. Further, the differences in perspectives upon significance of cost factors by the direct stakeholders of construction industry were also identified. Most significant cost factors were identified as; cost of materials, size of the projects, projects planning and the complexity of projects. Further, factors were categorised in to the five main categories. Construction parties' related factors contributed to the construction costs by 25%. Financial factors contributed to the costs by 21%. Construction item related factors contributed to the costs by 20%. Environmental factors contributed to the 18% while political factors affecting to construction costs by 19%. Most significant cost factors of each category were identified separately and a guideline was formed to help minimize building construction cost in Sri Lanka leading to a better sustainable construction practice.

Keywords: *Building Projects; Direct Stakeholders; Public Sector.*

1. INTRODUCTION

Poor cost performance in construction projects has become a major concern for both contractors and clients (Saleh, 2008). A clearer understanding of the cost determinants (Akintola, 2010; Alahakoon, 2012; Thanushan, 2012) is vital to achieve the desired level of accuracy of anticipated labour costs, material costs, plant and equipments in total cost estimation. The estimator need to be able to examine these factors and subsequently estimate, plan for, and mitigate the adverse effects of these factors on the project cost. Further accuracy of cost estimate will greatly affect the ability to deliver on time and within the budget (Hawang, Zhao, and Ng, 2013). Further, it has been observed that most accurate estimate leads to highest value for money to the construction client. However Hammed, Ismail, and Mohd, (2011) stated that cost overrun is observed as one of the most frequently occurring issues in construction projects worldwide and need to be studied more to alleviate this issue in the future. This trend is more severe in developing countries where these overruns sometimes exceeds 100% of the anticipated cost of the project.

The high demand for building construction coupled with tight monetary supply in public sector is stressing the construction industry to minimise costs in a country like Sri Lanka. The problem of high construction costs in all aspects of construction is becoming obvious. Consequently, substantial cost overruns are being observed in projects. This substantial increases in costs as compared to initial estimates, has brought about loss of client confidence in consultants, added investment risks, builders to add low profit margins, inability to deliver value to clients, and disinvestment in the construction industry. Therefore there is a need for a scientific study to be carried out to identity factors affecting to the construction cost in Sri Lanka in order to identify true construction costs. In the Sri Lankan context many researchers have been conducted on "construction cost factors for road constructions projects" as a whole. However a building project consideration has not been done. This research investigates possible

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ways and means to address the problem of "Identifying what are the factors affecting to building construction costs in public sector". Therefore the aim of the study is to identify the ways and means to reduce construction cost in public sector construction projects with the objectives as to, identify cost effective factors that are considered by estimators, identify reasons for cost overrun factors in building construction project, determine constructions costs factors severity ranking according to contractors, consultants and client and to derive a guideline on minimising building construction cost in Sri Lanka.

2. LITERATURE REVIEW

2.1. A RECENT PICTURE OF SRI LANKAN CONSTRUCTION INDUSTRY IN AN ECONOMISTS PERSPECTIVE

In Sri Lanka, as of most developing countries, the construction industry plays a dominant role in the economic activities of the country. According to Central Bank (2012) the construction industry accounts for about eleven percent of the nation's capital investment and nine percent of the Gross Domestic Product (GDP). Furthermore, the construction industry is said to have contributed about half of the total stock of fixed capital investment in the Sri Lankan economy (Central Bank Report, 2012). Husseini (1991) pointed out the industry also generates employment opportunities, which is only second to the government in providing the employment for labour.

Especially at the post war context, construction industry was at a boom in its economic cycle where, the country's economy also was experiencing a healthy run. However, when reaching the year 2011, the industry was pushed towards a recession and its effects were felt in all spheres of national economy (ICRA Management Consulting Services, 2011). Consequently, the state governments resorted to take foreign loans as a quick solution to the problem of lack of funds. However, some of the measures taken by government in order to revitalise the economy have further aggravated the situation. One obvious implication of this development is that the cost of imported raw materials and subsequently of the finished products has substantially increased (ICRA Management Consulting Services, 2011). These substantial increases were reported by Alahakoon (2012) have obvious negative implications for the major players and the industry; undermining the viability and sustainability of the industry.

Stakeholders to any industry are a group or individual who can affect or is affected by achieving the industry's objectives. The role of stakeholders as major players in industry dynamics are widely recognised and recorded. This pluralistic view of the identity of those who have an investment and an interest in an industry extends well beyond the traditional concept of "shareholders" to include client, consultant, builders, material suppliers, trade unions, communities, government agencies, etc. (Kasimu, 2012). The interest, influence and importance of various stakeholders in an industry could vary. Further, stakeholders can be categorised in to two groups as direct and indirect stakeholders. Direct stakeholders are having a major role in defining the construction cost of project with regard to a construction project.

2.2. SIGNIFICANCE OF IDENTIFICATION OF COST ESTIMATION AND OVERRUN FACTORS IN CONSTRUCTION PROJECT - BROADER VIEW

Cost estimation is particularly difficult in the construction industry, often leading to considerable cost changes that are explained by large uncertainties and uniqueness of projects (Barker, 2008). One might expect that cost changes have that same probability as completing the project below the cost estimate. According to the Jayasena (2006) selection of proper method of procurement is mostly affecting to the estimation of cost as well as final project cost. Although Kasimu (2012) identified lack of cost control in all of the project development phases can contribute to cost control problems, of particular interest is the time the client makes the decision to build. In the traditional method, this is often made towards the end of the design phase. Accurate budget estimates are critical to the initial decision to build process for the construction projects (Ameh, Soyingbe, and Odusami, 2010). According to the Oladapo (2007), Akpan and Igwe (2001) Project cost changes can be caused by rising costs from the initial stages of project to the final completion of project. Flyvbjerg, Holm and Buhl (2002) discussed that for the client, accurate cost estimates are vital for business decisions on strategies for asset development, potential project screening, and resource commitments for existing and proposed project developments. Accurate estimates are critical to the initial decision-to-build process for the construction of capital projects.

2.3 CONSTRUCTION COST FACTORS

Okpala (1988) investigated the causes of high costs of construction in developing countries and identified a total of 27 factors causing cost overruns and delays from the research. Okpala (1988) indicated twenty variables that could cause delays and cost overruns and seven other variables that could result in the escalation of construction costs without necessarily causing delay. Ismail, Aftab, and Ahmad, (2012) emphasised the effect of the economic situations of developing countries on the contractor's performance. Because of high competition between contractors, they accept very low margins of profits. In a study of the construction industry in developing countries like Nigeria, Omoregie and Radfort (2006) sampled the opinions of contractors, consultants and clients and they discovered 15 factors responsible for project delays and construction cost escalation. In another study, Elinwa and Silas (1993) identified 31 essential factors causing high cost of buildings with fraudulent practices and kickbacks ranked most important factor in developing countries. Frimpong, Oluwoye and Crawford (2003), in a review of developing countries, identified some factors as underlying causes of delay and cost over runs in construction projects. Furthermore, a study of the relative weight of ten major causes of business failure in the United States of America revealed construction cost related factors as mostly contributing to business failure (Kangari, 1989). In another new study in Nigeria, Kasimu (2012) has identified 41 cost factors while categorising to major five sections such as financial factors, factors related to the construction parties, factors related to the construction items, environmental factors and political factors.

In considering all the studies mentioned above, following forty one factors were identified as factors affecting construction costs via the literature survey. According to Kasimu (2012) factors affecting the construction costs can be categorised under following five main categories as mapped in Figure 1.

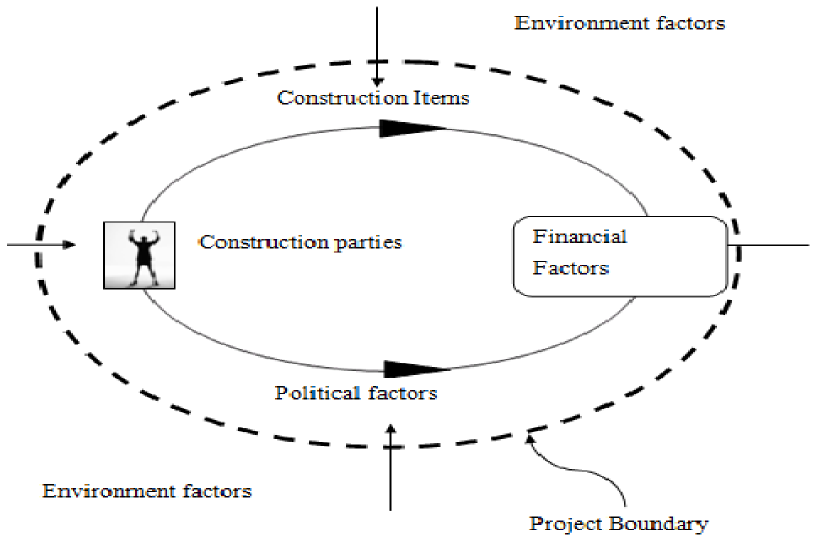

Figure 1: Major Factors Affecting Construction Cost
Source: Kasimu (2012)

Each of all factors categorised according to the Kasimu (2012) shows the relationships of all factors to the each factor. It shows the external factors are affecting to the all other factors significantly to the project boundary. Other factors are affecting to the most changes of the financial factors as a whole inside the project boundary. Table 1 summarise the identified different sub factors under each of the main five factors.

Table 1: Summary of Construction Cost Factors

Environmental Factors	Factors Related to Construction Parties	Factors Related to Construction Items	Financial Factors	Political Factors
Level of Competition	Project Planning	Cost of Material	Fluctuation of Prices of Materials	Supplier Manipulation
Complexity of Projects	Contract Management	Cost of Machinery	Project Financing and Payments	Fraudulent Practices and Kick Backs
Economic Condition	Long Period between Design and Time of Tendering	Transportation Cost	Mode of Financing, Bonds and Payments	
Project Location	Cost of Labour	Duration of Contract Period	Wrong Estimation Methods	
Social and Cultural Impacts	Contract Procedure	Additional Work	Inflation Pressure	
Number of Construction Going on At Same Time in the Western Province	Lack of Coordination and Allocation of Responsibilities between Designers and Contractors	Size of the Project	Insurance Cost	
Effects of Weather	Relationship between Management and Labour	Equipment Maintenance Cost	Currency Exchange	
Effects of Weather	Government Policies (Rules and Regulations)	Design Changes		
Number of Competitors	Poor Financial Control on Site	Waste on Site		
	Bureaucracy in Tendering Methods	Inadequate Production of Raw Materials by Country		
	Inadequate Labour Availability			
	Previous Experience of the Contract			
	Disputes on Site			
	Labour Nationality			
	Absence of Construction Cost Data			

Source: Kasimu (2012)

2.4. *WAYS OF MINIMISING CONSTRUCTION COST*

There are several ways in which cost of construction can be minimised. Fisk (1997) reveals two cost reduction measures. The first is the application of a value engineering concept, which aims at a careful analysis of each function and the elimination or modification of anything that adds to the project cost without adding to its functional capabilities. The second is to provide comprehensive and error free designs and specifications to avoid misinterpretations by the contractor or delay due to missing details. According to Cooke and Williams (2003) elimination or minimisation of design and specification, delivery delays and site wastes through formulation and implementation of effective material policy and material management may lead to cost reductions. In addition, Ashworth (1996) observed that profitable firms may be generating their revenues from the elimination of waste at both professional and trade practice levels.

Cost reduction measures also include: establishing firmly the requirements and features of the project at the onset before getting started; preparing the project team to do its best by getting members to sign off on capabilities and responsibilities; staying diligent about keeping the project the project on the right path through contract clauses that disallow significant changes once the project is underway; effective human resource management through effective motivation; and project tracking involving discerning early what area or paths are leading to dead ends and applying early corrective actions.

3. METHODOLOGY

A comprehensive literature survey was carried out by referring to published books, journals and articles to obtain existing knowledge on identify the construction costs factors affecting the costs of construction projects. According to the identified cost factors, a questionnaire survey was carried out according to the Delphi technique to obtain views among the construction professionals in public sector upon the factors affecting construction costs. Two Delphi rounds were conducted using questionnaires and ranking of the identified factors were done by using the severity index accordingly from contractors, consultant and clients viewpoints. The weighted mean, standard deviation, standard error of mean and coefficient of variation are used to aid the researcher in interpretation of the information. By the correlation coefficient, the extent to which two variables are linearly related to each other is measured. Three methods were used to determine association among the parties included in this study. These are the Spearmen Correlation, Rank Agreement Factor and the Kendall's Coefficient of Concordance. Cross tabulation involves placing the survey data into tabular form, from that the functional relationship of these data can be described therefore Cross tabulation of the Experience of Responders and Average percentage agreement for the cost categories were conducted. Finally in order to lay the groundwork for costs estimation accuracy, this study sought to discover the major variables affecting construction costs of building project and via ranking.

4. FINDINGS AND ANALYSIS

4.1. RESULTS OF DELPHI ROUND ONE

Principle of the first round of the Delphi methodology is to extort and recognise the factors which influence the construction costs in building projects. The round one was carried out from beginning to end using an open ended questionnaire and interviews among the selected expert panel. In this round 33 questionnaires were disseminated and 30 of them were collected in that time. In this round expert panel was given the factors, which are generally affecting Construction costs as the theory suggests. Expert panel was asked to identify the factors which are important in terms of construction costs in public projects. Further the panel was asked to suggest any other factors which are appropriate to be considered. Respondents have suggested Soil and land stability, Inadequate Specification, Delay in payment and Difficulties in importing materials as some additional factors, which are important to consider as factors affecting construction costs in building projects in public sector addition to the criteria provided. These factors were to be considered to the second Delphi round of the survey. Consequently 44 factors are the factors which have been considered in the second round excluding the factor Labour Nationality which has received 46.67% in the initial Delphi round.

4.2. RESULTS OF DELPHI ROUND TWO

The second round of Delphi method was mainly concerned about identifying significance of factors. Therefore severity index was used to rank the construction costs factors according to the costs significance. Cost of material was taken the highest severity index (84%) out of the other factors. Out of the 44 factors 5 factors were recorded with a Severity Index result more than the 70%. Further, 29 factors were recorded more than 50% of Severity Index value while 14 factors recorded lower than 50% of Severity Index value. Waste in site was recorded the least Severity index out of all 44 factors. Order of factors is shown in Table 2.

Table 2: Rankings of Construction Cost Factors

	Factor	Severity Index
1	Cost of Material	84
2	Size of the Project	77
3	Project Planning	76
4	Complexity of Projects	73
5	Previous Experience of the Contract	72
6	Contract Management	71
7	Economic Condition	69
8	Poor Financial Control on Site	68
9	Lack of Coordination and Allocation of Responsibilities between Designers and Contractors	67
10	Wrong Estimation Methods	67
11	Inadequate Specification	66
12	Level of Competition.	65
13	Relationship between Management and Labour	64
14	Project Financing and Payments	63
15	Number of competitors	62
16	Soil and Land Stability	62
17	Delay in Payment	61
18	Inflation Pressure	59
19	Cost of Labour	58
20	Design Changes	57
21	Fraudulent Practices and Kick Backs	56
22	Difficulties in Importing Materials	56
23	Fluctuation of Prices of Materials	55
24	Duration of Contract Period	54
25	Disputes on Site	53
26	Supplier Manipulation	53
27	Cost of Machinery	52
28	Inadequate Labour Availability	51
29	Absence of Construction Cost Data.	50
30	Contract Procedure	49
31	Mode of Financing, Bonds and Payments	49
32	Government Policies (Rules and Regulations)	48
33	Long Period between Design and Time of Tendering	45
34	Bureaucracy in Tendering Methods	45
35	Project Location	43
36	Additional Work	43
37	Number of Construction Going on at Same Time in the Western Province	42
38	Effects of Weather	41
39	Inadequate Production of Raw Materials by the Country	39
40	Equipment Maintenance Cost	38
41	Transportation Cost	37
42	Social and Cultural Impacts	33
43	Currency Exchange	32
44	Waste on Site	26

According to the first round, 44 factors were used to the second round and statistical techniques were used to the further analysis. According to the results of second round cost of material was recorded the highest mean value with least coefficient of variance (27.04%). However, eight factors were recorded between 30% - 40% of the coefficient of variance showing the higher agreement within the expert panel. 21 factors were recorded the below than 50% of the coefficient of variance showing the relatively high agreement between the expert panel. Further, the results of second round as showing the good ranking agreement between the tree groups.

Consultant - client (r_s = 0.75); Contractor - Client (r_s = 0.76); Consultant - Contractor (r_s = 0.81)

Cross tabulation contribute to place the survey data into tabular form to describe the functional relationship of collected data. The cross tabulation shows in Table 3 compares the tested group with their public sector experience.

46.67% - over 10 years of experience; 66.67% - over 5 year experience; 30% - over 15 year of experience

The hypothesis is to be tested whether consultants, contractors and clients are generally agreed on the rank of severity of cost factors. The two tailed (α = 0.05) t - test is suitable for this study.

Null Hypothesis H0 : $\rho = 0$ (There is no agreement between severity ranks of cost factors and there is no correlation of responses)

Alternative Hypothesis H1 : $\rho \neq 0$ (There is agreement between severity ranks of cost factors and there is correlation of responses)

SPSS computer software was used to calculate "t" value and the result of test hypothesis is as follows;

Table 3: Test Statistics Data

95% CI test statistic, T-Test of statistics = 0 (vs. not = 0), Degree of Freedom = 42 (44-2)		
$T_{0.05}$(42)	2.018	
T-Cal	For Contractor - Consultant	8.09
	For Contractor - Client	8.95
	For Consultant - Client	8.35

Therefore, the null hypothesis is rejected. According to test there is a relationship between the rankings. Therefore there to a 95% CI it can be concluded hat parties are agree on the severity of the factors and all parties were trustworthy in their responses.

4.3. LEVEL OF INFLUENCE ON THE FACTORS OF CONSTRUCTION COSTS

Accoring to the Kasimu (2012) cost of materials and insufficient time was the top cost significant factors. However, when considering top five costs factors as the research findings most of significant factors are agreed by Kangari (1989), Kasimu (2012), and Frimpong, Oluwoye and Crawford (2003). There are five important factors highly highlighted by the expert panel showing the high severity index. They are;

Table 3: Five Most Cost Significance Factors

Column Reference	Rank of Factors	Construction Cost Factors	Severity Index
9	1	Cost of materials	84%
18	2	Size of the projects	77%
19	3	Projects planning	76%
2	4	Complexity of projects	73%
30	5	Previous experience of the contract	72%

Cost of material is highly emphasised as a cost factor for the building construction costs. According to the Kasimu (2012) costs of material price will depend upon the fluctuation of material, absence of or shortage of funds to afford materials, high transportation costs, high taxes charge by government, materials shortage in religion. Further, Kasimu (2012), highlighted that size of project and insufficient planning lead to costs overruns. However the size of the project and project planning were found in this study as next most important factors showing the very close severity index and same ranking agreement. Top most important cost factors have shown a close high severity index over the other cost factors.

The factors recognised as least important factors in cost of construction are currency exchange and waste on site however the Kasimu (2012) agreed with findings. Moreover, Kasimu (2012) discussed that currency exchange as least construction cost factor. However, currency exchange affects directly other factors such as transportation costs and material prices when projects have special features like BOI approval. The top least five important cost factors as ranked by experts are shown in Table 4.

Table 4: Five Least Cost Significance Factors

Column Reference	Rank of factors	Construction Cost Factors	Severity Index
15	40	Equipment maintenance cost	38%
11	41	Transportation cost	37%
5	42	Social and cultural impacts	33%
39	43	Currency exchange	32%
17	44	Waste on Site	26%

According to the Kasimu (2012), Potts (2002), Kangari (1989), Elinwa and Silas (1992), and Frimpong, Oluwoye and Crawford (2003) agreed about the all cost factors identified by expert survey. Total of 44 factors were identified as construction costs factors concluded for Sri Lankan Context. Most of factors caused due to human nature. However, there were two factors identified as natural costs factors as effects of weather (Severity index 41%) and soil and land stability (Severity index 62%). Ranking of all factors implied that most of human related factors are contributed to the construction costs.

4.4. MAJOR FINDINGS IN RESEARCH

Factors of Construction costs were categorised in to five major groups. According to the Kasimu (2012) in developing countries, considerable percentage of 19% - 30% costs factors was contributed from the *group of construction parties,* 14% - 22% from *group of environmental* and 20% *of political factors,* 16%-20% *from financial factors, 20% - 23% from* construction item factors, . According to the research study cost contribution in Sri Lankan construction industry is about 25%. Hence this group of factors were identified as biggest impact on construction costs rather than the other groups. ; Environmental factors (18%), financial factors (21%), Construction item factors (20%) and Political factors (16%). However combination of environment factors and financial factors shown 39% similarly the construction parties and political group contribution to the construction costs. Construction party's related, financial factors and construction item related groups were contributed to the more than 64% of construction costs while political and construction item related groups showing 36% of the construction costs significantly.

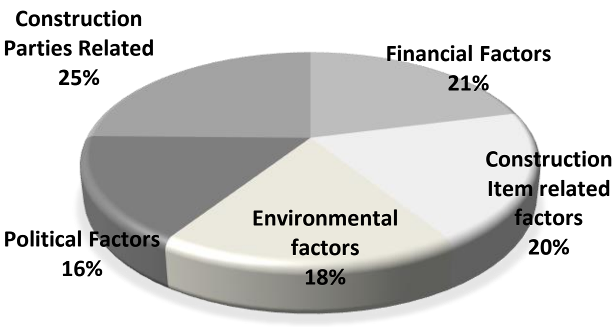

Figure 2: Groups Cost Distribution Over the Total Construction Costs

The research study shows a general good agreement level in raking of the factors affecting construction costs. However, highest ranking agreement is between the consultant and client over with contractors.

Contractors have ranked the critical factors affecting construction costs as; *(18) Size of project, (9) cost of material, (19) project planning, (20) contract management, (37) wrong estimation methods*. Consultants have ranking the cost factors ranking; *(9) cost of material, (18) size of the project, (37) wrong estimation method, (19) project planning and (3) economic condition*. Finally client have rank the factors affecting to construction costs; *(9) Cost of materials, (3) economic conditions, (19) project* *planning, (27) poor financial control on site, (30) previous experience of the contract.* The five least important factors agreed by the experts; *(40) equipment maintenance costs, (42) social and cultural impact, (45) currency exchange and (45) waste on site.*

The cross tabulation results show and compare the experience of the tested groups of experts. About 65% of the experts that were analysed belong to the over five years and about 30% of the experts having more than the 15 years of the experience. About 46.67% experts having more than the ten years experience. According to the Kasimu (2012), there was good agreement between the groups while proofing that the Kendall's rank correlation is 0.93 showed the grate agreement between the groups of consultant, contractor and client. Most of the costs factors based on *parties related* are critically influence the construction costs by 25% with respect to the other categories in Sri Lanka. Consultants and clients believe that costs of building material are extremely server factor for construction costs. Environmental factors affects to the construction costs by 18% while political factors influencing the construction costs by 16% in the Sri Lanka. When considering the Sri Lankan context also *political influence* on the construction costs is considerable. Financial factors affect to the construction costs in 21% and item related factors affects in 20%.

5. CONCLUSIONS

Construction sector is a major industry which significantly contributes to the country's economy. Wrong or inadequate identification of construction cost factors usually course to a project failure. Therefore, identification of factors that define the construction cost is an important research area in current practice. Especially for public clients it is critically important to identify the factors that define costs for their projects to give good value for people's money in the country. Hence, this research study focused to address the problem of reducing the construction costs in public sector projects. The attempts were made to identify and analyse the factors which are critically influencing in the construction costs in public sector building projects.

This research study was based on the Delphi methodology to extort a set of exceptional factors which are influencing construction costs and to determine the level of importance of each factor for the public sector. The initial identification of the influencing factors affecting to construction costs, was carried out through a comprehensive literature survey. All together 41 construction costs factors were identified for the first round of Delphi method and out of 41 factors 40 factors were identified to be considered in public sector costs factors and 4 new factors were identified to be considered. Level of importance of each costs factor was analysed through the results of the second of Delphi rounds. According to the results 44 factors were identified as significant costs factors for the public sector.

Construction industry is specific and uniquely characterised. Since, the costs of a construction project is highly related to five most costs significant factors as agreed by construction professionals as cost of materials**,** size of the projects, projects planning, complexity of projects and previous experience of the contract.

Research concluded that identified the most costs significance factors for the factors affecting to construction costs in public sector projects. Basically construction costs of building projects are ascertain by the tendering procedure according to the government rules and regulations. In the public sector projects, costs identification can be done effectively in pre and post contract stages. Therefore, identification of costs factors in the each stage is very important to reduce the construction costs and avoid future costs overruns. In this research found out that several factors could be identified in the pre contract stages as costs factors. Hence, adaption of identified costs factors to the projects is a responsibility of the projects team in initially stages. However, most of cost factors could be foreseen by the pre contract stages. According to the top 20 cost factors identified, showed that 80% - 60% of the cost significant factors could be foreseeable by the project team in the pre contract stages. Therefore, proper investigation and understanding will result to give good value to the public money.

When considering the post contract stage, project team could be foreseeable risks of cost increasing in the projects. Hence, project team should be take actions to identify costs factors which can be course to the costs overruns. When considering the top 20 cost factors, 20% - 40% of cost factors belong to the post contract activities in the post contract stage itself. Hence identified costs factors in the research, is more important to the project team in controlling and identifying the possible costs in pre and post contact stages which would lead for a better sustainable construction practice.

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FACTORS AFFECTING THE PSYCHOLOGICAL HEALTH OF FOREIGN WORKERS IN THE SAUDI CONSTRUCTION INDUSTRY

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ABSTRACT

The Saudi construction industry is considered as the fastest growing and largest sector in the Gulf region with ongoing construction projects valued at US$475 billion. The booming construction sector in Saudi Arabia portrays a positive impression. However, the occupational health and safety (OHS) situation paints a different picture. Particularly, the psychological health of foreign workers is at a great risk due to the unfavourable work conditions they are faced with. The OHS related studies conducted in this region so far have focused on technical, managerial and physical aspects of safety and have neglected the psychological health of foreign construction workers. This indicates an urgent need for research into this area. Hence, this research explored what factors affect the psychological health of migrant workers in the Saudi construction industry. An interview survey with 30 experts from the Saudi construction industry and other relevance sectors were conducted. A thematic analysis of the data collected from the interviews identified several critical factors that affect the psychological health of foreign construction workers, including: low wage; delay of payment; withholding workers passports; mistreatments by supervisors; long shifts without breaks; lack of vacations; poor accommodations conditions; and disregard for mental health of workers. The study lays the foundation for establishing a mechanism to combat the factors that deteriorate the psychological health of foreign workers in the Saudi construction industry.

Keywords: *Foreign Construction Workers; Occupational Health and Safety; Psychological Health; Saudi Arabia.*

1. INTRODUCTION

Saudi Arabia is in the process of rapid economic growth as a result of an increase in oil prices over the last few years. The Saudi economy is ranked as the world's twenty-third largest and one of the world's fastest growing countries; per capita income in 2007 was US$20,700 and it is forecasted to rise to US$33,500 by 2020 (SAGIA, 2011). The Saudi construction industry sector is considered as the fastest growing and largest market in the Gulf region with on-going construction projects valued at US$475 billion and business investment opportunities through to 2020 are estimated at US$1.4 trillion (USSABC, 2009).

The booming construction sector in Saudi Arabia provides a positive impression. However, the occupational health and safety situation paints a different picture. According to GOSI annual reports for the years 2003 - 2009, the construction sector is represented heavily in workplace-related accidents. For example, in 2009, the percentage of the construction sector was 50.2% of all work related accidents. A vast majority of them are foreign workers. For example, records in 2012 showed that 36,367 people had a work related injury, and more than 98% of them were foreign workers from different countries (GOSI, 2013).

Hohnen and Hasle (2011) criticised the current practices of Occupational Health and Safety Management (OHSM) systems which heavily focus on technical aspects and neglect complex workplace issues such as psychosocial risks. Hohnen and Hasle (2011) and Widerszal-Bazyl *et al*. (2008) observed that employers are either not aware or unwilling to see psychosocial risk as an integral aspect of work health and safety.

Psychological health are among the factors that affect workers on construction sites (Choudhry and Fang, 2008). For example, Siu *et al*. (2004) reported a strong correlation between job dissatisfaction and

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worker psychological conditions with the rate of work-related accidents and injuries. Psychological health can be defined as "state of well-being in which the individual realises his or her own abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community" (CSA, 2013).

The psychological health of workers in developing countries face more challenges than in developed countries. For example, a report by World Health Organisation pointed out that developed countries are more familiar about how to deal with work related stress more than developing countries (WHO, 2007). Among those developing countries, Saudi Arabia has been chosen for study because of its specific nature with significant challenges on the psychological health of foreign workers in the construction industry. There is a high proportion of foreigners, 7.5 million, who represented more than 25% of residents (Arabnews, 2013). Saudi Arabia recorded 266 suicides cases in 2006, more than 60% of them were foreigners (Al-Awsat, 2008) and this rose to 787 suicides cases in 2009 (Al-Ibrahim, 2012). This study aims to investigate the factor affecting the psychological health of foreign construction workers in Saudi Arabia.

2. LITERATURE REVIEW

2.1. STUDIES ON OHS MANAGEMENT IN THE SAUDI CONSTRUCTION INDUSTRY

Jannadi (1995) carried out research on the impact of human relations on the safety of construction workers. The study focused on construction and maintenance workers who were involved in pipeline activities for a large construction company in the city Dhahran, Saudi Arabia. The aims were to shed some light on the factors that significantly influence the safety performance of construction projects. The findings showed that small groups had better safety records than big groups. According to the research, this could be because they got along well, and discussed their personal problems with each other. Therefore, the friendly atmosphere among crew members is important in improving safety. The relationship between management and workers plays a significant role in improving safety performance. Moreover, the competition between workers, and working under pressure had a negative impact on workers' safety performance (Jannadi, 1995).

Jannadi and Al-Sudairi (1995) conducted research to evaluate the safety programs of construction companies in the Eastern Province of Saudi Arabia. The study noted that as the firm gets larger, its safety program becomes more formal and tends to result in a better OHS performance overall. It was found that safe firms had the following qualities: field safety representatives have direct relations with top management; training; good reporting systems and safety awards to workers (Jannadi and Al-Sudairi, 1995).

Jannadi and Assaf (1998) tried to assess the level of safety practiced in different construction projects in Saudi Arabia. They assessed whether safety levels differ according to the project size or not. The researchers found that safety levels in construction sites vary according to project size. They also established that safety records in large projects, generally maintained by large international companies, are significantly better than smaller ones (Jannadi and Assaf, 1998).

Jannadi and Bu-Khamsin (2002) undertook research to find out the factors that affect the safety performance level of construction contractors, and to know the extent that these factors affect safety performance. The authors conducted a literature review to identify significant factors affecting safety performance of industrial contractors. Moreover, they developed a preliminary list of main factors and their associated sub-factors and they conducted formal interviews with key safety personnel of contractors and with certified safety experts to assess the identified factors. The results showed that the main factors were management involvement, personal protective equipment, emergency or disaster planning and preparation, ionisation radiation, scaffolding and ladders, crane and lifting equipment, electrical equipment, excavation, trenching and shoring, and mechanical equipment (Jannadi and Bu-Khamsin, 2002).

Jannadi (2008) studied the risks associated with trenching works in Saudi Arabia. The research discussed the general safety aspects of trenching work and introduced and evaluated the government's role in trenching safety. In order to minimise the risks related to trench work the research recommended that contractors should consider important issues such as providing all safety equipment, training their people for safe work practices, and applying all safety measures on job sites at all times. Moreover, the government has a role to play, which is conducting site inspections and enforcing safety with penalties when they are required (Jannadi, 2008).

The topic of OHS management in the Saudi construction sector is poorly researched. The review on the previous research related to OHS in the construction industry in Saudi Arabia indicates that the number of studies remains very low and do not reflect the true size and seriousness of the problem, which indicate an urgent need for further critical research in this area. Moreover, most studies have focused on technical, managerial and the physical safety aspects and have neglected other significant causes of the problem like the psychological health of construction workers.

2.2. FACTORS AFFECTING THE PSYCHOLOGICAL HEALTH OF WORKERS

One of the earliest studies related to occupational psychological health was a study by Cohen and Margolis (1973). They reviewed the research conducted using different classifications which were: detect occupational hazards with the use of behavioural methods, neurophysiological and behavioural disorders from physical conditions and chemical exposer, individual differences influencing worker health and safety, job stress and workers' health and psychological strategies for enhancing the practices of health and safety.

Sauter *et al*. (1990) tried to develop a national strategy in a comprehensive manner to promote and protect workers' psychological health in USA. The authors highlighted that the psychological disorders are the leading problem for the workers' occupational health. The suggested strategy focused on the general concern of psychological disorders in the field of occupational health of those being usually investigated under the general topics of "job stress" which are amenable to interventions in the workplace (Sauter *et al*., 1990).

Braun (2001) studied Turkish workers' psychological health and intercultural communication in the American-German workplace in Germany. The author described the historical background of the Turkish immigration to Germany and explained the harsh situation that they faced such as discrimination, violence, harassment, murder and burning houses by/from local extremists in order to expel them from the country. The study pointed out the Turkish workers struggled in the new environment to adjust psychologically. Their study revealed "participants felt significantly more positive about working with Americans than with Germans on several dimensions of psychological health, including happiness, confidence, satisfaction, and comfort" (Braun, 2001).

Siu *et al*. (2004) tested the relationship between safety climate, psychological distress and job satisfaction (psychological strains), and safety performance. The authors argued that workers who had large performance pressure focussed on work completion rather than safety procedures. They surveyed workers from construction sites in Hong Kong. Their findings partially supported the hypothesised model that safety attitudes and psychological distress predict accident rates and occupational injuries. According to the study result, the mediator between accident rates and safety attitude was psychological distress (Siu *et al*., 2004).

3. RESEARCH METHOD

The aim of this study was to explore the factors affecting the psychological health of foreign workers in the Saudi construction industry. It was realised that an interview survey with different experts from the construction industry and related sectors is a practical and effective way to collect data needed. The interviews took place in Riyadh, the capital city of Saudi Arabia, where all construction companies hold offices. Altogether thirty (30) interviews were conducted and the interviewees included: construction workers, construction managers, construction supervisors, site engineers, and other experts from related disciplines such as psychologists, social workers, OHS authority professionals and insurers.

A thematic analysis using Nvivo software was conducted on the qualitative data collected from the interviews. The issues, challenges, problems and suggestions presented by the respondents were broken down into a number of general themes. Then, in winnowing the themes, phrases that may be integrated were joined as a single concept. Then the phrases were linked to each other, as concepts may be interrelated, for the purpose of identifying the problems affecting the psychological health of workers.

4. STUDY FINDINGS

Eight critical factors that affect the psychological health of foreign construction workers are discussed here, which are directly related to the practices of construction companies and can be treated as internal factors to the construction organisations.

4.1. LOW WAGES

Construction companies are paying one of the lowest wages. The current wage is around US$266 per month, which is considered very low by respondents who compared their income with other sectors. This low wage does not allow them to live a decent life because they end up sending most of their income to their families back home. For example, workers complained that with the low wages they receive it is difficult to buy proper food; one worker stated that he had not eaten meat for weeks and just had bread and vegetables because he could not afford. Another worker spoke of the costs of calls. He uses a cellular phone to communicate with his wife. He just communicates by text messages because he cannot afford the expensive price of voice calling.

Moreover, an employee of the General Organisation for Social Insurance (GOSI) indicated that some companies do not provide them with the actual statistics and figures, especially with the real amount of salaries that are being paid to their workers. He further said that fewer amounts are declared so as to reduce the annual premium. This kind of dishonesty in reporting would have a serious impact on workers when accidents happen to them that they can receive only a small compensation from insurance.

4.2. DELAY OF PAYMENT

Delaying the wages of workers in construction projects is commonly found in Saudi Arabia. Salaries may be delayed for long periods, sometimes for months. This irregularity led protests and strikes in spite Saudi authorities and law prevent any demonstrations or protest rallies. This culture severely impacts the psychological health of workers. For example, a project manager recalled that a worker from his project committed suicide for not being able to cope with the life pressures caused by a long delay of payments from his employer.

4.3. POOR ACCOMMODATIONS CONDITIONS

Housing problems are common issues at most construction sites in Saudi. For example, a site supervisor said that some companies provide mattresses on the floor or bunk beds but the workers were all lumped together in one room. Moreover, labour camps are often overcrowded, unhygienic and uncomfortable. These affect workers' morale and mental health. Moreover, they cannot have adequate rest to recover from the tiredness.

4.4. WITHHOLDING WORKERS PASSPORTS

In Saudi Arabia, some negative practices like withholding workers' passports are common; especially passports belong to workers from development countries. A respondent who had worked there as an engineer said that the company management tried to withhold her passport but she refused and she thought that because she was from a western country the company did not put further pressure on her. A respondent said that workers' passports are sometimes withheld by management because this is their "hold" on workers, which allows them to delay their payments, extend the stay without workers' willingness and put them in any project or working condition even if the workers do not like.

4.5. *MISTREATMENTS FROM SUPERVISORS*

Respondents indicated that inhumane treatment at work was a common issue. Workers would suffer from harsh words and physical abuse by supervisors. Based on the responses, these inhuman treatments consisted sometimes of physically hitting workers should they fail in their performance.

One of the supervisors said that management of the construction company believes in the concept that being employers, they have the right to control the workers and demand from them quality and work productivity through their presence of mind and not just the body alone. They work for a living, so they have to conform to the standards of the company which starts off with presence of mind, focus, and concentration at work. This comment indicates the appalling mind set of many construction supervisors in Saudi Arabia.

4.6. *LONG WORK SHIFTS WITHOUT BREAKS*

Respondents expressed long work hours without breaks as an important problem on construction sites. A number of interviewees commented on the long work hours, like, from 6 a.m to 5 p.m. The long work hours call for reasonable work breaks, like a short time for a quick nap, coffee, or a drink of water. Moreover, working such long hours in the extreme weather can be very exhausting. However, workers are not allowed to have such short breaks. Even traveling for a long time in a non-air conditioned bus to go to work and to return from work on a very hot weather condition, especially in the desert area, is already stressful enough and exhausting.

Moreover, a project manager indicated the inadequacy of rest for workers and time to prepare for the workers' dinner. They have to travel for another two hours from the construction site to the place of accommodation. The long work hours did not allow the workers to have adequate rest once they were back in their sleeping quarters or respective accommodation.

4.7. *LACK OF VACATIONS*

The contracts between construction companies and workers allow them to have two months of paid vacations every two years. However, some of the workers accept their companies offer not to take vacations and keep working in return of getting the ticket money. Even if this practice is legal, the psychological experts said that workers as human beings need regular breaks. Being apart from their families and having to work continuously can have serious negative effects on their mental and physical conditions.

4.8. *DISREGARD FOR MENTAL HEALTH OF WORKERS*

A vast majority of construction workers in Saudi Arabia are foreigners who are breadwinners of their respective wives and families whom they have left behind in their home countries. There are difficulties in obtaining permission to bring their families to live with them in Saudi Arabia. Workers thus tend to live bachelors' lives to save some income. The psychologist observed that one common problem among workers is that they suffer from what is called the "Adjustment Disorder", whereby they face difficulties in adjusting to new conditions. He said that the social, family, homesick and other variables and hard conditions cause lots of pressure on the workers. He further cited recent statistics in Saudi, where the rate of suicide occurrences among foreigner workers is higher. Companies do not consider this important factor nor do they have any system in place to help workers adjust to the new environment gradually. Rather they treat workers as if they were machines.

5. CONCLUSIONS

The construction industry focusses more on the physical health of workers and do not give much attention to their psychological state. Occupational health psychology is a new area of study, which is relevant to labour and human resource management. This is evidenced by the lack or even absence of programs within construction companies that look into the welfare of workers' psychological, mental, or emotional state. Ideally, however, workers "should be seen as an integral part of the business and not just instruments to be exploited and discarded after the project".

Management's consideration of workers' psychological problems and their underlying reasons will help in improving workers' psychological health. Since psychological health is an intrinsic factor involved in the health and safety of workers, there is a need for more attention from construction companies to better understand and manage the psychological health of workers. This paper explored some of the factors affecting the psychological health of migrant workers in the Saudi construction industry namely: low payment, delay of payment, poor accommodations conditions, withholding workers passports, long work shifts without breaks, mistreatments from supervisors, lack of vacations and disregard for mental health of workers,. The study paves the way to devise a mechanism to combat workplace conditions that deteriorate the psychological health of foreign workers in the Saudi construction industry. Further studies are underway to develop an intervention framework for minimising the effects of these conditions on foreign construction workers.

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FACTORS INFLUENCING SAFETY BEHAVIOURS OF CONSTRUCTION WORKERS

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ABSTRACT

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 behaviours of the worker. Thus, studying the people factor in OSH is an effective way to manage OSH at work sites. The paper therefore focuses to investigate and prioritise the factors affecting construction workers' safety behaviours.

The study was structured in several steps. Initially in-depth knowledge gained regarding the research stream which was sorted upon the degree of relevance to the study. A total of 18 factors affecting construction workers' safety behaviours were identified through an extensive literature survey. Data collection was carried out through a survey which consisted of two rounds. The first round was conducted to validate the factors found in literature; to the Sri Lankan context and in the second round, experts were asked to rate those factors according to their degree of influence. Experts' rankings were used to calculate the Mean Score of Influence (MSI) of each factor and according to the MSI values, the factors were prioritised.

Findings of the study revealed the most influencing personal factor was age while the most influencing organisational factor was OSH incentives. The least influencing factors were work-mates' safety concern and provision of PPE respectively under the categories, personal and organisational. These findings could be helpful in better understanding the construction workforce and in designing OSH systems for the construction industry.

Keywords: *Construction Industry; Construction Worker; Occupational Safety and Health; Safety Behaviours.*

1. INTRODUCTION

1.1. OCCUPATIONAL SAFETY AND HEALTH AND CONSTRUCTION INDUSTRY

Occupational Safety and Health (OSH) encompasses the social, mental and physical well-being of workers that is the whole person (Alli, 2008). Thus, successful OSH practice requires the collaboration and participation of both employers and workers in health and safety programmes, and involves the consideration of issues relating to occupational medicine, industrial hygiene, toxicology, education, engineering safety, ergonomics, psychology, etc. (International Labour Organisation (ILO), 1996). The ultimate goal is an organisation aiming to improve its OSH performance, so that accidents and ill health are eliminated and work forms part of a satisfying life to the benefit of both the individual and the organisation (Health and Safety Executive (HSE), 1997).

Construction is the activity which creates all types of new facilities, as well as the maintenance and repair of existing facilities. Construction activities such as working at heights, demolition, removal or disturbance of asbestos, work at trenches or shafts, temporary supports for structural alterations, powered mobile plant, explosives, confined spaces, work that is in, on or near: electrical installations or services; telecommunications towers; pressurised gas distribution mains or piping; contaminated or flammable atmospheres; chemical, fuel or refrigerant lines are often relate to high risk activities (Rameezdeen, 2006; WorkSafe, 2013). Thus, the industry is considered as one of the most hazard and accident prone of industries worldwide. This fact is often proven by the statistics relating to construction

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accidents. 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 statistics, in 2003-2004, there were 3,760 major injuries in construction in the UK (HSE, 2005). More alarmingly, during 2004-2005, there were 69 construction fatalities in the UK, representing one-third of all worker deaths in that period (HSE, 2006). Moreover, in the US construction sector, there were 817 recorded fatalities in 2012 (Bureau of Labor Statistics (BLS), 2013). Only in years 2011 and 2012, there were an estimated total of 1.4 million lost working days: 818 thousand due to ill health and 584 thousand due to workplace injury in the UK construction industry (HSE, 2013). Thus, it is evident that the poor safety performance of the construction industry continues to give international cause for concern.

Sri Lanka is also 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 and Wimalaratne, 2012). Further, though 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 as reported in other countries such as USA (Chau *et al*., 2004), UK (Sacks *et al*., 2009), Hong Kong (Siu, *et al*., 2004) and Singapore (Chau and Goh, 2004). The annual accidents in the construction sites were 750-900 and among them 50-60 were fatal (Amarasinghe, 2011). Further, this annual figure was represented a more than 30 percent of accidents which was about 13 times higher than in the other industries in Sri Lanka (Rameezdeen, *et al*., 2003; Amarasinghe, 2009). Thereby, Sri Lankan construction industry is in a proven need to adhere to OSH more than any other industry.

1.2. SAFETY BEHAVIOUR

An accident is commonly known as an unwanted event that is never scheduled or planned. Raouf (2011) defined occupational accidents as unplanned occurrences which result in injuries, fatalities, loss of production or damage to property and assets.

Abdelhamid and Everett (2000) indicated that, workplace accidents in construction occur due to three root causes such as (1) failing to identify an unsafe condition that existed before an activity was started or that developed after an activity was started, (2) deciding to proceed with a work activity after the worker identifies an existing unsafe condition, and (3) deciding to act unsafely regardless of initial conditions of the work environment. They further highlighted that inefficient management decisions, unsafe acts of workers or co-workers, non-human-related events, and unsafe condition of the sites have become natural part of the construction site, continuing construction accidents (Abdelhamid and Everett, 2000). Further, more than 80% of accidents were due to employee behaviour or the human factor, in the form of acts or omissions, and thus safety behaviour has become a critical concept (Burton, 2012).

Heinrich (1931), been the pioneer of this concept, asserted that most safety problems (almost 90%) are the result of human error, which he called unsafe acts. His ratio of 88:10:2 states that 88% of accidents were caused by unsafe behaviours, 10% by unsafe conditions, and the remaining 2% by unpreventable causes. Later in 2006, a similar accident ratio that is 80:20 ratio was given by Hemoud, and Al-Asfoor (2006), broadly concerning unsafe behaviours (80%), and unsafe conditions (20%). This ratio was further improved as 96:4 if human factor aspects such as equipment/process design and work procedures to have an influence on the unsafe conditions (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%) (Hemoud, and Al-Asfoor, 2006). As such, it indicated that the human unsafe acts element is even more contributing to accidents. Thus, it is apparent that the human factor in managing OSH in an organisational setting is of utmost important. Hence, improving safety behaviours to reduce unsafe acts by the employees becomes a proven need. As a result, boosting of the behaviour based approach to OSH management is believed to be ensuring method to reduce injury rates.

The behavioural based approach to safety is focused exclusively on the observable, measurable behaviours critical to safety at a particular facility (Burton, 2012).The application of behavioural research to the solution of human problems is building and demonstrating the first effective and reliable technology of behaviour change in human history (Cambridge Centre for Behavioural Studies, n.d.). In workplaces with troublesome rates of unsafe performance, safety behaviour programs, properly implemented, produce significant improvements in safe performance and major reductions in workplace injuries and illnesses (Cambridge Centre for Behavioural Studies, n.d.). Thus, it is important to recognise safety behaviour of workers in improving the overall safety performance of an organisation. By identifying the factors that enhance the safety behaviour of workers, how safe behaviours can be inculcated within the construction industry could be examined. Thus, the research focuses on safety behaviour of construction workers and the influencing factors of those.

1.3. SAFETY BEHAVIOUR OF CONSTRUCTION WORKERS

Literature provided a number of factors that have influence on safety behaviour of construction workers. These factors can be broadly grouped under two main categories, namely, 'personal' and 'organisational'. The personal factors included 'Age' (Hinze, 1997; Sawacha *et al*., 1999; Carpenter, 2002; Parker, 2007; Seixas, 2008; Choudhry *et al*., 2009), 'Marital Status' (Fang *et al*., 2006; Choudhry and Fang, 2008), 'Number of Dependants' (Fang *et al*., 2006; Choudhry and Fang, 2008), 'Educational Level' (Hinze, 1997; Carpenter, 2002; Parker, 2007; Seixas, 2008; Masood and Choudhry, 2012), 'Knowledge on Safety' (Fang *et al*., 2006; Idirimanna and Jayawardena, 2011; Masood and Choudhry, 2012), 'Experience' (Siu *et al*., 2003; (Choudhry and Fang, 2008; Masood and Choudhry, 2012), 'Gender' (Hinze, 1997; Carpenter, 2002; Parker, 2007; Seixas, 2008; Masood and Choudhry, 2012), 'Drinking habits'(Fang *et al*., 2006; Masood and Choudhry, 2012), 'Work related pressure'(Choudhry and Fang, 2008), and 'Work-mates' safety behaviour' (Sawacha *et al*., 1999; Choudhry and Fang, 2008).

Under the category, 'organisational factors', a total of eight factors were identified as 'Management commitment'(Sawacha *et al*., 1999; Pidgeon and O'Leary, 2000; Mohamed, 2003; Choudhry *et al*., 2007), 'Provision of Personal Protective Equipment (PPE)' (Sawacha *et al*., 1999; Choudhry and Fang, 2008), 'Tidy site' (Choudhry and Fang, 2008), 'Safety training and awareness' (Wilson, 1989; Mohamed, 2003; Choudhry and Fang, 2008), 'Site layout' (Choudhry and Fang, 2008), OSH monitoring and feedback systems' (Sawacha *et al*., 1999; Pidgeon and O'Leary, 2000; Mohamed, 2003), 'OSH incentives'(Sawacha *et al*., 1999; Choudhry and Fang, 2008), and 'Employment type'(Pidgeon and O'Leary, 2000; Rowlinson, 2003).

In this research, these identified factors were validated to the local context through an expert survey. This is discussed under next section.

2. RESEARCH METHOD

The research was structured into several steps. Initially in-depth knowledge gained regarding the research stream which was sorted upon the degree of relevance to the study. In literature, a total of 18 factors influencing safety behaviours were identified. In order to get the identified factors validated for Sri Lankan construction industry, a preliminary survey (1st round of the survey) was undertaken. Hence the survey was designed into two rounds.

Table 1: Interviewee Profile

Interviewee Group	Interviewee	Years of Experience
Group A	General Manager - Projects (1)	20+
	Safety Engineer (2)	10+
	Safety Officer (3)	12
Group B	Deputy General Manager - Project Coordinating (4)	24+
	Manager - OSH (5)	15
	Health and Safety Executive (6)	9
Group C	Project Manager (7)	19+
	Manager HSE (8)	20+
	Safety Officer (9)	8+

In round 1, three group discussions were held with the management of three reputed construction companies in Sri Lanka who dominate the industry with construction of majority of building projects done and ongoing in the country. (refer Table 1 for interviewee groups' profile). Each interview was held for 40-45 minutes. At the beginning of the discussion, a brief introduction of the research was provided to the interviewees with the purpose of explaining the background and the objectives of the research. Then the identified 18 factors were introduced under two categories, personal and organisational. Behaviours of these factors were discussed and elaborated. Further, other specific factors with regards to Sri Lankan construction context were elicited. Subsequently, the original list of factors was moderated according to these experts' opinion.

In round 2, interviews were conducted to attain the interviewees' judgements on how those factors would affect safety behaviour of local workers. All the nine interviewees from the three groups of round 1 were individually approached for this exercise. A 5-point Likert scale (5 being the most influential) was used to elicit the subjective decisions on degrees of influence of the validated factors to safety behaviour of local workers.

3. RESEARCH FINDINGS AND DISCUSSION

3.1. *INFLUENCING FACTORS OF SAFETY BEHAVIOUR*

In round 1 of the survey, experts in all three groups agreed with all 18 factors identified through the literature survey. However, though the 'gender' is important on safety behaviour of workers, experts pointed out that as there are no female workers currently working on construction sites of their companies, the relevancy of this factor to Sri Lankan context remains questionable. Hence, this factor was deleted from the list. Moreover, an additional factor, 'previous exposure to OSH accidents' was recommended.

When organisational factors were considered, all the factors but 'employment type' was agreed as of substantial influence to safety behaviour. Experts showed that, type of employment has less cause for safety behaviour of a person. They clarified that a person's safety depends not on his employment type but on his personal and environmental factors. This may be due to all type of employment in the construction industry involve high risks. Table 2 denotes the moderated list of 17 factors, categorised under Personal and Organisasional factors from round 1.

Table 2: Moderated List of Factors Influencing Safety Behaviour of Construction Workers

Personal Factors	**Organisational Factors**
1. Age	1. Management commitment
2. Marital status	2. Provision PPE
3. Number of dependants	3. Tidy site
4. Educational level	4. Safety training and awareness
5. Knowledge on safety	5. Site layout
6. Experience	6. OSH monitoring and feedback systems
7. Drinking habits	7. OSH incentives
8. Work related pressure	
9. Work-mates' safety behaviour	
10. Previous exposure to OSH accidents	

3.2. *DEGREE OF INFLUENCE OF IDENTIFIED FACTORS*

The degree of influence of the validated factors on safety behaviour of construction workers were obtained using individual interviews of the experts and the data collected from the second round of the interviews were then analysed according to the Mean Score of Influence (MSI).

Table 3: Degree of Influence of Factors on Safety Behaviours of Construction Workers

Personal Factors	MSI	Rank
Age	4.89	1
Work related pressure	4.78	2
Previous exposure to OSH accidents	4.67	3
Knowledge on safety	4.55	4
Experience	4.55	4
Educational level	4.00	6
Drinking habits	3.89	7
Number of dependants	3.78	8
Marital status	3.55	9
Work-mates' safety behaviour	3.44	10

Organisational Factor	MSI	Rank
OSH incentives	4.89	1
OSH monitoring and feedback systems	4.67	2
Safety training and awareness	4.44	3
Management commitment	4.33	4
Tidy site	4.00	5
Site layout	3.67	6
Provision PPE	3.44	7

Table 3 presents the MSI values and ranking of the influencing factors accordingly. According to these values, it is apparent that both personal and organisational factors are more or less importance to safety behaviour of construction workers. Moreover, each factor in both the categories has reach a MSI value over 3.00, implying that they have a substantial influence on safety behaviours. Among them, Age, work related pressure and previous exposure to OSH accidents can be identified as the highest three influential in personal category while OSH incentives and OSH monitoring and feedback systems are the top influential in organisational category. The following section discusses the rationale of these ratings.

3.3. PERSONAL FACTORS

Age - Hinze (1997) identified that substantial influence has been determined for demographic factors as personal characteristics as age, and other personal information (gender, marital status, education level, working experience in the industry) can influence individual safety behaviour. Siu *et al*. (2003) investigated age difference in safety attitudes and safety performance in Hong Kong construction workers with data from 374 Chinese construction workers from 27 construction sites. The study found that the older workers exhibited more positive attitudes toward safety. Experts also have observed that the workers who are older in age are more cautious about work safety than youngsters in the industry. Young people are energetic and often reckless, but as they age the physical agility and daringness of workers tame and they tend to behave more safely for their own protection.

Work related pressure - It is common that the work pressure is high when the deadlines are nearing. As a result lack of consideration to perform work safety is observed among the workers, due to their urging to take shortcuts while performing their tasks (Choudhry and Fang, 2008). Experts further pointed out that when the company has to finish a planned project on time, workers have to perform the task quickly in order to get the job done rather than work safely. Thus, the value of safety over performance pressure is often overlooked, not only by workers but also the management, and that could lead to higher accident rates.

Previous exposure to OSH accidents - This factor was added to the existing list by the experts interviewed, stating that workers who have faced occupational accidents tend to be more careful onsite.

These workers know the consequences of an accident and difficulties associated by experience. So, they strongly feel the need to behave in a safer manner while they work.

Knowledge on Safety - Knowledge on safety also plays a major role in enhancing safety behaviours of employees (Fang *et al*., 2006; Idirimanna and Jayawardena, 2011; Masood and Choudhry, 2012). Further, experts also clarified that if the workers don't, or even worse, don't want to understand why or how safety matters in construction, there is a bigger chance of them behaving unsafely during their work hours. So, knowledge in safety matters very much to develop safety behaviours onsite.

Experience - More experienced workers in the industry are less likely to be behaving unsafe manner while they work (Siu *et al*., 2003; Choudhry and Fang, 2008; Masood, and Choudhry, 2012). Experts suggest that, experience let the workers know what sort of danger they are dealing with and what would the consequences be of work related accidents in construction. Thus, workers with more years of experience in the industry would naturally accustomed to safe behaviours than those with less experience, as per the experts. Young workers are more prone to accidents than old workers. This suggests that with the passage of time workers get more experience and are thus aware of safety requirements. The best trained construction workers 'learned by doing' or by gaining experience. New workers watch what experienced workers do and then copy them. Nevertheless, it is a continual learning process and one's perception of doing the work can be changed or modified by subsequent experiences. They revealed that pooling of knowledge and experiences provides more options in solving problems. Experts suggest that, experience let the workers know what sort of danger they are dealing with and what would the consequences be of work related accidents in construction.

Educational level - Educational level does have a positive impact on safety behaviour of workers (Hinze, 1997). Experts agreed that it is easier to maintain safety standards when the workforce consists of individuals with a sound educational background. According to the experts, individuals with good education see the importance of following safety guidelines in work. Their workforces consist mostly of junior school pass outs and people with secondary education (Advanced Level – A/L). According to the interviewees, people with secondary education are easier to handle and to get complied with safety practices than those with an education level of primary or lower.

Drinking habits - Drinking habits can also affect the safety behaviour of workers. Alcohol impairment at work can put the drinker and others at greater risk of injury, particularly in workplaces where heavy machinery is involved (Frone, 2009). It has been estimated that 20%–25% of workplace accidents are alcohol related (Henderson *et al*., 1996). According to the experts, drinking habits can alter a person's risk perception and influence their attitude about safety.

Marital status and number of dependents - Workers also tend to be more careful in what they do when their social responsibilities are higher (Fang *et al*., 2006; Choudhry and Fang, 2008). Experts did argue that workers who are married and have more dependants in their families tend to follow safety instructions and guidelines onsite than others. However, they insisted that a detailed survey is necessary to pinpoint just how much, because when dealing with people, the results can be surprising.

Work-mates' safety behaviour - Safety behaviour of fellow workers can be a possitve influence to improve a worker's safety behaviour onsite (Sawacha *et al*., 1999; Choudhry and Fang, 2008). All the three groups agreed that no worker wants to be highlighted with a bad reputation, in case of safety or otherwise. They asserted that, it may psychologically affect the worker not to fall out of the flock by working safely, if their work-mates follow the safety protocols and work safely during construction. However, as clarified by the experts, this factor doesn't always motivate the employee to follow safety rules. It might depend on the mood, and attitude of the worker.

3.4. ORGANISATIONAL FACTORS

OSH Incentives – Tangible reward for following OSH protocols and procedures are recognised as a good way to get the workers to comply with OSH systems in an organisational setting. (Sawacha *et al*., 1999; Choudhry and Fang, 2008). Experts all agreed that incentives have always been a strong motivator for workers, OSH or otherwise. When OSH incentives are awarded the organisation is giving the worker a good reason to behave safely at work. According to experts it is a tangible reward for the worker. Thus, OSH incentives play a major role in influencing safety behaviours on site.

OSH monitoring and feedback mechanisms - OSH monitoring systems and feedback mechanisms must be there to monitor employee behaviour towards safety. If these systems are well design to capture every error and rectify them, employees automatically adhere to these systems (Sawacha *et al.*, 1999; Pidgeon and O'Leary, 2000; Mohamed, 2003). Experts argued that organisations already have these systems but the problem is the continuous monitoring. They viewed that without continuous monitoring any good system can fail eventually. Also, monitoring process will give the workers a sense of been watched over and that will definitely influence safety behaviours. Further, experts pointed out that the workers might not take the system seriously without proper monitoring of the system.

Safety training and awareness - According to OHSAS 18001:2007 - Occupational Health and Safety Management Systems, an introduction to safety policy together with an effective training programme is necessary for an organisation. Experts identified training and awareness programmes for workers is also important. They will be a guide to proper and safe way of behaving while work and will clarify the need of safety while work. All three organisations stated that they conduct safety briefs twice every week and safety induction is a must for their employees.

Management commitment - Management commitment to safety is vital if an organisation wants to promote safe behaviours among the workers (Choudhry *et al.*, 2007). Current management practices of OSH include but not limited to controlling the workers' safe and healthy behaviour, centralised OSH management unit, resources and insurance policies, OSH documentation, and OSH committee (De Silva and Wimalaratne, 2012). According to experts, there is so little that can be expected from workers regarding safety if the top management's attitude to safety is dull. An interviewee viewed that, people want to get the work done one way or another. So if they see no commitment from the top management to anything l*et al*ong safety, the management cannot expect much from them.

Tidy site - Cleanliness and tidiness of the construction site is a must to ensure accident free environment (Choudhry and Fang, 2008). The need of tidy site is been emphasised in quality standards as well. For example, as mentioned in specification for buildings (2012) published by Architectural Services Department of Hong Kong, under the British Standards' General specification for buildings (2012), cleanliness on site is been acknowledged as important. It states that the materials and plant need to be stored neatly, rubbish and debris as they accumulate must be removed and site must be kept clean and tidy. Experts highlighted the importance of clean and tidy sites for improving safety behaviours. It is part of improving the job condition to minimise the risk of accidents in the physical environment.

Site Layout - The planned and organised site layout can be helpful to mitigate the risk to construction workers and influence safety behaviours in them (Choudhry and Fang, 2008). The experts agreed that sites which are properly planned are more likely to improve safety behaviour by reducing the causes of accidents on site. For example by guarding machinery or prohibiting access to certain areas accidents can be prevented on site. Also, by properly planning and establishing labour camps, the risk to workers onsite can be minimised.

Provision of PPE - Provision and use of the correct type of equipment for a job, and the provision and use of protective clothing and equipment are prerequisite for improving safety behaviour (Sawacha *et al*., 1999; Choudhry and Fang, 2008). Experts clarified that it's organisations' responsibility to provide those to the workers for they enable the worker to safely perform his work. However, experts revealed that although they provide their workers the necessary PPEs, they do not where them unless they are closely supervised. Often the organisations have to force the workers to wear PPE while they work.

4. CONCLUSIONS

The paper presents the findings on factors influencing construction workers' safety behaviour, validated and prioritised by the industry experts. 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 two categories; namely, personal and organisational. Under personal category, study identified ten factors, namely, age, marital status, number of dependents, educational level, knowledge on safety, experience, gender, and drinking habits, work related pressure, work-mates' safety behaviour. Management commitment, OSH monitoring and feedback mechanisms, Safety training and awareness, OSH incentives, Tidy site, Site layout, Employment type and provision of PPE are the factors identified under organisational category.

These factors were validated and moderated by the industry experts in the round 1 of the preliminary study undertaken. Two factors, namely, 'gender' and 'employment type', were omitted from the list considering the Sri Lankan context and significance to the subject matter, respectively. An addition was made to the list as 'previous exposure to OSH accidents'. This moderated list of factors was then rated using a Likert scale of 1 to 5 (5 being the most influential) for their degree of influence on safety behaviour of construction workers, by the same set of experts and the results revealed that all the factors are substantial when it comes to safety behaviour. However, age and OSH incentives were the most influential in their respective categories while work-mates' safety behaviour and provision of PPE were the least influential.

These findings could be helpful in better understanding the construction workforce. That understanding can be utilised in designing and implementing OSH systems for the construction industry. Also, the knowledge acquired from this study can be helpful in deciding how to influence the workers to behave in a safer manner onsite.

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FACTORS THAT INFLUENCE THE FORMATION OF CONSTRUCTION PROJECT TEAMS FOR SUSTAINABILITY: CONSIDERATION OF SPECIFICITY

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ABSTRACT

The importance of effective multi-disciplinary organisational teams has been a central aim of management research in the construction industry for over 50 years. As design and construction processes are reconsidered to include sustainability there is a need to consider procurement approaches which facilitate more effective coordination between supply chain partners. Such procurement approaches require a strong theoretical basis and also need to consider parties other than the client, design team and contractor. This paper reports on ongoing research about the factors that influence the formation of construction project teams. The focus of the study was how buying organisations' collaborative procurement strategies interact with a range of specialised trade contractors and to identify those factors which affect their selection during the project development. The theoretical basis for the study was adapted from transaction cost economics and the research strategy was mixed. This paper reports upon the quantitative second phase which used a survey of 570 professionals working for UK contracting organisations. The findings of the research suggest a future approach is required which seeks to increase the specificity of trade contractors to the developing project which will facilitate an improvement in knowledge transfer relating to alternative low carbon approaches to design and construction.

Keywords: *Knowledge Transfer; Supply Chain Integration; Sustainability.*

1. INTRODUCTION

It is widely recognised that a project is successful when is completed on time, within budget, in accordance with specification, and delivers value for money for clients and end-users (Davis and Love, 2011; Eriksson, 2010; Egemen and Mohamed, 2005). However construction clients are dissatisfied with the performance of the industry (Meng, 2010; Karim *et al*., 2006; Beach *et al*., 2005; Miller *et al*., 2002). In the United Kingdom (UK), the construction sector has been criticised for underperforming. Time and budget overruns are common and excessive resources are required to correct defects. Poor productivity, variable construction quality and client dissatisfaction are problematic areas for the sector (Kadefors, 2011; Eriksson *et al*., 2007; Egan, 1998; 2002). Some of the root causes for poor performance have been attributed to the sector's features: fragmentation, the uniqueness of construction as a product, outdated procurement methods, and little or no integration between the project actors (Eriksson *et al*., 2007).

The UK construction industry has a long-standing reputation for being adversarial, demonstrated by poor relationships between members of project team, which in turns, results in numerous problems including poor project performance and limited number of long-term relationships between project participants. Given the severity of the problems and the obvious failing of the industry's approach towards integration of key project team members and processes, it was of little or no surprise that Sir John Egan's report (1998) challenged the industry to address its under-performance. In a follow up review, the industry's 'Strategic Forum' laid down challenging targets for improving its management practices within its 'Accelerating Change' report (Strategic Forum for Construction, 2002). As Wolstenholme (2009) recently highlighted, the industry needs to maintain its focus on integrated supply chains. It has been suggested that practice from manufacturing can be transferred to the construction industry (Errasti *et al*., 2007; Akintoye *et al*., 2000) and that organisations extended their management

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approaches beyond the boundaries of organisations to include their suppliers (Christopher and Towill, 2001; Gunasekaran and Love, 1998).

Organisational collaboration includes a wide range of practices intended to facilitate greater inter-firm cooperation amongst those involved to increase the whole supply chain network performance (Goulding *et al*., 2012; Barlow *et al*., 1997). In the construction sector, it may be short-term and project-orientated or long-term and strategic in nature (Goulding, 2012; Beach *et al*., 2005; Barlow and Jashapara, 1998). In the case of the later, it is usually concerned with optimising the relationship's resources through closer collaboration to exploit long-term benefits, whereas the former focus more on agreeing project governance issues to secure immediate project benefits (Errasti *et al*., 2007; Beach *et al*., 2005). Collaborative sourcing is often perceived as the optimum approach to achieving supply chain improvement through the development of more effective customer-supplier relationship (Humphrey *et al*., 2003).

Unfortunately, whilst there is sufficient evidence to suggest that the collaborative relationships in construction developments have been increasing of recent years, it has been reported that not all the collaborative relationships in construction developments are successful (Ng *et al*., 2009; Miller *et al*., 2002; Dainty *et al*., 2001). Its acceptance amongst the main contractors, subcontractors and their suppliers in the UK construction industry is still not considered to be universal (Mason, 2007; Beach *et al*., 2005). This is due to the industry being affected by macro-economic, organisational and technological factors that serve to restrain change to its structure, practices and products. The external environment is a key factor in the contingent organisation of projects (Hartmann and Caerteling, 2010; Moore, 2002). Collaboration requires that firms undertake a range of transactions with other organisations that are informed by the context of their market. According to Bidgoli (2010), supply chain management should incorporate strategic differentiation in order to achieve value enhancement, operational efficiency improvement, and cost reduction. Indeed, the application of supply chain initiatives has been criticised for being generic and without due consideration for different subcontract trades (Ross and Jaggar, 2005, Ross and Goulding, 2007; Ross, 2011), and a need to change traditional thinking across the whole supply chain (Goulding *et al*., 2012). It is also acknowledged that the level of uncertainty associated with different procurement strategies varies greatly which can influence the formation of construction teams (Dow *et al*., 2009). Similarly, subcontract trades exhibit different intrinsic complexity and asset specificity (Ekstrom *et al*., 2003). Consequently, it is argued that the constructor's procurement approaches used during project development will vary significantly over a range of subcontract trades (Ross, 2011). Thus, there is a call for a better understanding on how contractors' collaborative procurement strategy interacts with different specialist trade contractors in their supply chain (Ross, 2011; Bidgoli, 2010).

Crouse (1991) offers the following as potentials of a balanced collaborative relationship: offer the ability to leverage internal investments; emphasis on core competencies; leverage core competencies of other firms; reduce capital needs and broaden products offerings; gain access or faster entry to new markets; share scarce resources; spread risk and opportunity; improve quality and productivity; having access to alternative technologies; provide competition to in-house developers; use a larger talent pool and satisfy the customer. A theoretical framework that has merit in exploring relationships between organisations is transaction cost economics. The following section of the paper considers how this may be adapted to consider its approach to construction supply chains.

2. DEVELOPING A THEORETICAL FOUNDATION

Researchers have suggested that despite many efforts to develop a better understanding of procurement systems, that they lack an economic foundation (Ross, 2011; Eriksson and Laan, 2007; Arditi and Chotibhongs, 2005; Ngowi and Pienaar, 2005; Kale and Arditi, 2001) and that a transaction economic approach may assist in the understanding of the relationships that exist between contracting parties (Chiang, 2009; Winch, 2001). Coase (1937) pioneered the theory of Transaction Cost Economics (TCE) and suggested that the allocation of resource in market economies is not only based on market prices but also through entrepreneurial decision making unrelated to prices. As suggested by Williamson (1985), the end product of efficient governance of transactions is competitive advantage, which requires tailoring procurement procedures to transaction characteristics (Eriksson, 2006). It has been observed that long term contract with agreed limits, rather than, a series of contracts could reduce the costs of discovering the relative prices of contract agreements (Kale and Arditi, 2001).This reduction in the contract agreements costs leads to the efficiency of the firm. The term “marketing costs” (price mechanism related costs) used by Coase can be defined as the costs of discovering the relative prices of suppliers and agreeing separate contracts with each supplier. Dietrich (1994) contends that there is possibility for contracting costs reduction if a factor of production (a contractor) did not have to place a series of contracts each time with other factors of production but in fact replaced them with one long term contract with agreed limits. This reduction in the use of the spot markets results in lower cost of contracting and increased the efficiency of the firm.

The TCE approach has further been developed to explain human and environmental factor costs. These have been identified as bounded rationality (limits to the acquisition and processing of information), opportunism (self-interest seeking with guile) and asset specificity (the investment on specific assets by agents that lock them in to agreements). Williamson (1981) introduced a new term to replace marketing costs and defined it as transaction costs. According to him, the attributes of a transaction determine what constitute the efficient market, hierarchy or relationship. The key properties that affect the transaction include: bounded rationality, opportunism, small numbers bargaining, and information impactedness. Williamson (1985) argues that these are considered to be transaction difficulties and associated with cost increase when transactions are characterised by: asset specificity, uncertainty, and frequency. Moreover, Williamson (1981) affirmed that the hierarchy (firm) could reduce problems through a reduction in the number of exchanges, which increased frequency resulting in learning.

The important transactional features are asset specificity, uncertainty and frequency (Williamson, 1985). Transactions characterised by high asset specificity and high uncertainty need a more complex governance mechanism than standard transactions with low asset specificity. The significance of frequency is in relation to the costs incurred. Complex governance mechanisms may incur large costs, which must be recovered in future transactions. If transactions are infrequent, it is unlikely that the actors will invest in expensive and complex governance mechanisms.

Asset specificity has been defined as the ‘‘degree to which the assets used to conduct an activity can be redeployed to alternative uses and by alternative users without sacrifice of productive value’’ (Williamson, 1996, p. 105). According to Williamson (1985, p. 95), four different types of transaction specific asset investments can be identified: site specificity, which is related to the geographical location of an investment; physical asset specificity, which is related to specialised equipment and tools; human asset specificity, which is associated with employees’ knowledge, expertise and learning by doing; and dedicated asset, which represent a discrete investment in generalised production capacity that would not be made but for the prospect of selling a significant of product to a specific customer.

Governance such as markets, firms and hybrids have unique characteristics. Furthermore, it has been observed that more integrated governance structures are associated with a higher degree of asset specificity, more complex transactions or more frequent exchange (Ross, 2005; Liu *et al*., 2009). To economise transaction costs, transactions with different properties are matched with governance modes. These different properties were to be investigated by this research and an approach to data collection was required to investigate the approaches taken by different organisations.

3. RESEARCH APPROACH: DATA COLLECTION

The population chosen for the survey was main contracting organisations in the United Kingdom. The aim was to explore trends, attitudes, or opinions of participants as well as key factors influencing supply chain collaborative strategies of contracting organisations involving different specialist trade contractors and the Chartered Institute of Building (CIOB) and Kompass UK were seen as the professional bodies that companies with worldwide construction and professional expertise and experience would be members. As a result, they could be considered as a population that would represent good practice on collaborative working exchange within their various supply chain networks. After piloting, the main survey was sent by mail on 15 February 2013 with a return date of 01 March 2013. The cover letter emphasised the support of the participants as well as highlighting the importance of the research to the industry in general, and the value of the participants' response in particular. The variables and their measures were drawn from a detailed analysis of the literature which cannot be reported here due to space limitations. Table 1 summarised the variables that were defined and measured within the questionnaire.

Table 1: Research Variables

Areas Measured in the Questionnaire	Items Used for Analysis	Description of Scales and How Factors Were Obtained
Demographics variables	Title Employer size Decision making role Experience	Eight groups Four groups Four groups Five groups
Organisational variables	Subcontract strategy Organisation size : Turnover Number of employees	Dichotomous Five groups Five groups
Collaborative supply chain	Benefit Collaborative technique Performance	Total score of the 8 item factor Total score of the 7 item factor Total score of the 9 item factor
Subcontract trades interactions	Procurement approach Strategy assessment Strategy differentiation	Mean score of the 2 item scale Total score of the 14 item factor Total score of the 14 item factor for each trade

4. DATA RETURNS

A total of 65 questionnaires were returned from the initial mailing representing 11.4%. The initial response rate was considered as low. Since any analysis based on this return would lead to bias in the results and may be considered as unreliable (O'Leary, 2010; Newman, 2007). Consequently, follow up procedures were implemented. The participants who had not responded to the initial survey were identified and in the week commencing 11 March 2013, a follow up letter was sent to them. The follow up letter included an additional copy of the questionnaire and reminder. A final total of 107 questionnaires were returned representing a response rate of 19%. This was considered to still be low response rate; however, in construction it is not unusual to report survey response of such rate.

5. RESULTS

The data was coded and entered into SPSS, respondents were asked to provide information relating to their current role and position, how long they had held this position for in their current organisations as well as their experience in dealing with subcontractors' procurement. A summary of the respondents' characteristics are displayed in Table 2.

Table 2 shows that construction managers constituted the largest group (25%), followed by others, (17%), then project managers (15%), quantity surveyors (11%), procurement managers (10%), managing directors (10%), supply chain managers (8%), site managers (5%) respectively. The largest group of field of operation was contractor in civil engineering, 32 (31%), followed by contractors who carried out both building and civil engineering projects 30 (29%), building contractors 29 (28%)and other 13 (13%) of the respondents.

Table 2: Demographic Responses

Demographic	Categories	N=107	Valid %
Job Title	Managing Director	10	9.9
	Supply Chain Manager	8	7.9
	Construction Manager	25	24.8
	Project Manager	15	14.9
	Quantity Surveyor	11	10.9
	Site Manager	5	5.0
	Procurement Manager	10	9.9
	Others	17	16.8
	Missing	6	
Current Position	<5	4	3.8
	5-9	17	16.3
	10-14	25	24.0
	15-20	26	25.0
	>20	32	30.8
	Missing	3	
Experience	<5	6	5.7
	5-9	7	6.7
	10-14	21	20.0
	15-20	18	17.1
	>20	53	50.5
	Missing	2	

6. SUBCONTRACTING AND SUPPLY CHAIN RELATIONS

Respondents were asked to indicate the average number of subcontractors used in each trade during the last financial year and the average length of relationships they have had with their subcontractors. Table 3 summarises the data captured for of each category. The survey shows an average value of 7 subcontractors were included within the selected list at project tender stage. This is almost the same in all the categories, with the exception of mechanical and electrical of 4.36 being the least and a highest of 7.76 for finishes subcontractors.

Table 3: Number of Subcontractors Used in each Trade and Length of Relationship

	Average Number of Subcontractors	Average Length of Relationship in Years
Brickwork	6.98	6.80
Groundwork	7.54	7.54
Steelwork	6.57	10.95
Mechanical and Electrical	4.36	13.70
Roofing	6.62	6.69
Finishes	7.61	5.77
Average	6.61	8.58

Table 4 below shows the primary reasons for subcontracting work packages among the respondents. Respondents were asked to indicate their agreement or disagreement on a five-point scale to a number of statements about subcontracting. These statements had been drawn from an analysis of previous research considering subcontract relationships (Lavelle *et al*, 2007, Hartmann and Caerteling, 2010). The question also encouraged respondents to give their own reasons if there were no reasons that were applicable to their answers. The responses to this question would provide an indication of some the motives for employing different groups for subcontractors and could give a deeper insight into procurement approaches more commonly used by main contracting organisations.

Table 4: The Primary Reasons for Subcontracting

Reasons for Subcontracting	Strongly Agree % (N)	Agree % (N)	Slightly Agree % (N)	Slightly Disagree % (N)	Strongly Disagree % (N)	Mean
Reduce liability exposure	63.6 (68)	36.4 (39)	0 (0)	0 (0)	0 (0)	4.64
Reduce overhead cost	14.0 (15)	69.2 (74)	16.8 (18)	0 (0)	0 (0)	3.97
Reduce construction cost	12.2 (12)	57.9 (62)	30.8 (33)	0 (0)	0 (0)	3.80
Market volatility	5.6 (6)	56.1 (60)	38.3 (41)	0 (0)	0 (0)	3.67
Reduce maintenance cost	8.4 (9)	41.1 (44)	44.9 (48)	5.6 (6)	0 (0)	3.52
Reduce construction time	9.3 (10)	25.2 (27)	45.8 (49)	19.6 (21)	0 (0)	3.24
Value to the client	10.3 (11)	19.6 (21)	47.7 (51)	22.4 (24)	0 (0)	3.18
Better workmanship	2.8 (3)	25.2 (27)	46.7 (50)	25.2 (27)	0 (0)	3.06

Overall, eight different reasons were presented to respondents. The strongest agreement was found in the need for reducing liability exposure with 63.6% of the respondents and a mean of 4.64. This was followed by reducing overhead cost with a mean of 3.97, reducing construction cost (3.80), market volatility (3.67), reducing maintenance cost (3.52), reducing construction time (3.24), value to the client (3.18) and better workmanship (3.06). The high ranking given to liability exposure gives an indication of prevalence of disputes and legal claims in the construction industry (Costantino *et al*., 2001). One reason for the high agreement for reducing liability exposure might be that contractors have been employing the system of subcontracting to shift risks. It could also mean that contractors use more market relationships in subcontracting than collaborative relations. However, emphasis given to construction cost signalled that where collaborative relationships may develop due technological interdependency, contractors may take advantage to reduce transaction cost.

This was further explored when considering the data analysis which focused upon the contractor subcontractor collaborative working relationship. The summary of this analysis is shown in Table 5.

Table 5: Factors Influencing Contractor-Subcontractor Collaborative Working Relations

Factor	Total	SME	Large	F Stat	P-Value
Technology performance of subcontractor	4.34	4.26	4.47	3.687	0.058
Client procurement route	4.21	4.11	4.26	0.088	0.240
Market intensity	4.12	4.08	4.11	0.453	0.426
Bilateral dependence	4.10	4.03	4.25	0.374	0.542
Project complexity	4.09	3.89	4.20	0.538	0.465
Subcontractor organisational capability	4.03	3.97	4.06	1.988	0.162
Reputation of subcontractor	3.93	3.83	3.98	0.144	0.705
Limited numbers	3.83	3.77	3.94	0.349	0.550
Subcontractor - main contractor interdependency	3.79	3.58	3.91	5.544	0.061
Location of project	3.77	3.44	3.97	0.085	0.771
Subcontractor specialisation	3.48	3.42	3.51	0.091	0.763
Subcontractor specificity	3.47	3.22	3.60	8.247	0.075
Workload of subcontractor	3.34	3.26	3.47	0.662	0.430
Price specificity	2.78	2.53	2.97	0.050	0.864

This analysis may suggest that large firms enter into more collaborative procurement arrangements than SMEs. Akintoye and Main (2007) acknowledge that more collaborative types of procurement arrangement tend to be undertaken by large construction companies due not only to complexity and size of the contract, but also the opportunity to provide continuity of work. In spite of large organisations rating the factors for collaboration in construction generally higher than the SMEs, the two groups did not differ on each of the factors for collaborative working in construction development at the 0.05 significance level.

The most important factor identified by both set of respondents was "technological performance" of the subcontractor. The results support a study by Ng *et al*. (2009) that found technological capability very vital in keeping subcontracting firm in business and thus making a collaborative approach both credible and reasonable. It may also suggest that collaborative relationship in construction development between the main contractor and subcontractor is in response to taking advantage of technical skills of subcontractors or timely use of expertise by the main contracting organisation to respond to the opportunity created. This was followed by the procurement strategy of main contracting organisation.

7. DISCUSSION

The aim of this study was to explore whether construction buying organisations employ different collaborative working relationship strategies when interacting with different specialist trade contractors within their supply chain networks during project development.

Langford and Male (2001) have argued that construction is a highly interconnected industry involving material components suppliers, the use of subcontractors within a geographic market and the extensive social connections that are in place between individuals who work for the various organisations in construction. It has been claimed that low entry and exit barriers exist within construction that are different to other forms of industry (Ross, 2011), these relate to a low capital requirement, and that the organisational capability that exists within organisations is difficult to protect and can be poached easily whilst the products produced are unspecific. According to Ng *et al*. (2009), the product in construction could be considered as a service or an end product. A differentiation in competition for a service includes reputation and product differentiation occurs through pre-qualification mechanisms. As clients adopt pre-qualification processes that require an organisation to have a reputation and good track record, this can be considered as an entry barrier to other organisations and as such organisations seek to ensure that their reputation is protected. This view is however countered by others, who suggest that the price is the final arbiter when selecting a contractor (Lavelle *et al*., 2007).

The results of the survey would suggest that the market is extensively used to select subcontractors. Price was not found to be the only determinant. Contractors require offsetting risk to their subcontractors and the approach they take varies with the specialism of the subcontractor. The activities of the construction industry and the parties within it can be considered as a network of transactions or contracts. The nature of these transactions poses a challenge in the choice of the correct governance structure for the implementation. The framework of transaction costs has been developed to include searching and gathering information about the buyers and sellers, writing and negotiating contractual agreements, as well as administering the agreement (Williamson, 1981, Lorange and Roos, 1993).

The results from the survey pointed to the direction that buying organisations had strategy for developing closer economic bonds with selected specialist trade contractors and suppliers. The survey suggested that contractors still use competition to select their specialist suppliers and that the number of competitors varies with given trades. This is more a feature of a market response than the development of strategic differentiated approaches to the management of the supply chain.

8. CONCLUSIONS

The framework adopted for this research has suggested that several factors influence the adoption of form of governance and that these can relate to the subcontracting organisations, organisational factors, the procurement approach taken by buying firms and the market determinants which were found to influence a subcontractor's specificity.

One of the key future challenges to the construction industry is to develop designs and construction techniques which result in lower embodied carbon and lower carbon in use. This will require specialist knowledge exchange between designers and constructors, which is often “locked up” in supply change organisations who consider it to be a transactional asset. Further work is required in order to identify the value placed on this transactional asset and the barriers to its exchange. It would appear that procurement approaches which increase the specifity of the subcontractor reduce the number of prospective partners and also increase the opportunity to exchange knowledge. This appears to be occurring with the more specialised subcontractors however has not extended to the less specialised contractors.

In order to facilitate better knowledge exchange about low carbon construction techniques, organisations should seek to reduce the number of supply chain competitors and move towards a serial approach to placement of contracts. This will allow for an accretion of knowledge over time between buying organisation and specialist contractors, this will ultimately improve the low carbon attributes of the construction product and contribute to the industry meeting the challenge of sustainability.

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IDENTIFICATION OF ERRORS THAT ARE BEING MADE IN PREPARING BOQS IN SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

The Bill of Quantities (BOQ) is a vital document in both pre contract stage and post contract stage of any construction project. The BOQ impacts three important aspects of a project namely time, cost and quality. Therefore, it is crystal clear that if there is any error in BOQ that would directly affect to the construction project. Since all the stakeholders involved in construction projects are extremely concerned on time, cost and quality aspects, it is critical that the BOQ for the project is error free.

Errors occur during both preparation stage and pricing stage of the BOQ. The BOQ preparation errors may relate to pricing errors as well as have an impact on the time, cost, and quality of the project. However the study is focused on identifying most common BOQ preparation errors and find solutions to minimise those errors to support sustainable procurement practice. Initially a semi structured interview was carried out to identify errors made in preparing BOQs and find reasons for the errors. Eventually, a questionnaire survey was done to identify the most significant errors that are made and how those errors would affect the project.

The surveys revealed that quantity errors as the most common error during the BOQ preparation stage, which becomes critical based on the type of the procurement method adopted. Employing experienced person as a reviver was identified as the most preferable solution for minimising preparation errors. Further it was found that people involved have a greater impact on the BOQ preparation process and its accuracy.

Keywords: *Bill of Quantities; Cost; Errors; Quality; Time.*

1. INTRODUCTION

The construction industry performs a vital role in the development of a country. Especially in Sri Lanka, the contribution of construction industry for the Gross Domestic Product (GDP) was 39.3% in 2012 (Central Bank of Sri Lanka, 2013). However, with the involvement of large number of stakeholders the industry has become more complex (Enshassi, Mohamed, and Abushaban, 2009). Therefore, construction projects needs to be managed effectively, to have a successful outcome at the end. In order to have an effective management several standard practises have been established within the industry.

BOQ is a widely used standard document around the world, which specifies the qualitative and quantitative aspects of each and every essential part of a construction project (Rashid, Mustapa and Wahid, 2006)). Further, BOQ can be seen, as a source of valuable information for not only the management of a project's cost but also the management of the project, because project cost management is an integral part of project management for balancing competing demands among cost, time, quality and scope of a project (Rashid *et al*., 2006).

BOQ is a document emerged after the industrial revolution of the 19th century in Europe (Bandi and Abdullah, 2012). Since the origin of the document its purposes has not changed a lot other than the method of measurements and technology. According to the literature even the BOQ has not changed, usage of the BOQ has decrease drastically with the invention of the new procurement methods. However, BOQ has numerous uses and advantages with regard to financial matters in construction and it is the most appropriate financial decision making tool in the construction industry. Therefore, BOQ is

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a useful document for the construction even though there is a decline in its usage rate. Further, there are various reasons for decline the usage of BOQs, and BOQ errors have become a significant issue for decline in the usage even though there are no much more researches, studies or attention from the industry practitioners towards BOQ errors.

Contract is a binding document between two or more parties; therefore none of the parties to the contract like to have documents with errors within the contract document, particularly regarding financial aspects. Therefore as the financial decision making tool within the contract document BOQ should be a error free document in order to obtain reputation and trust of users and hence to increase the use of the BOQ as a financial decision making tool in the construction for longer time. Even though generally the consultant prepare and the prospective contractors price the BOQ, errors in preparation as well as pricing affect the decline in the usage of the BOQ because cost is a major parameter and a concern of a client.

Since BOQ is an important document in project management it should be a reliable source for all the stake holders of the project. However, contractors prefer to have BOQ only as a source of information and not as a part of the contract, due to the risk of errors (Davis and Baccarini, 2004). Accordingly to remain as a reliable and useful document BOQ needs to be of almost no errors during both preparation and pricing stages.

1.1. IMPORTANCE AND USES OF BOQS IN CONSTRUCTION

BOQ can be identified as a document specifying the qualitative and quantitative aspects of each and every essential parts of a proposed construction project (Rashid, *et al*., 2006),. The BOQ has two primary uses in pre contract and post contract stages (Davis, *et al*., 2009). In pre contract stage the BOQ assists contractors in the formulation of tender document, through breaking down the contract works in a formal, detailed, and structured manner for tendering. Moreover, in post contract stage the BOQ assists contractors and Quantity Surveyors (QS) in preparation of interim payments and valuing variations, as well as it provides a financial structure for contract administration (Davis, *et al*., 2009).

Than the identified primary tasks BOQ performs several other roles during both pre contract and post contract stages. During pre contract stage, BOQ can be used for giving sense of control of projects, in terms of cost and finance, requesting competitive tenders from contractors, price the work on precisely the same basis, thus allowing for the fairest bidding, projecting cash flow and budgeting and assessing tenders (Rashid *et al*., 2006). When considering post contract stage BOQ serves as a post-contract administration tool and provides a basis for the evaluation of progress payments, proper and common basis for the valuation of variations, basis for comparing a contractor’s price with current trends in the market and basis for management to determine the likely causes of risk factors (Davis, *et al*., 2009).

Thus, BOQ becomes a critically important document in construction industry especially under traditional procurement method. However, the greatest misunderstood aspect of construction contracts is the uses of the BOQ and further clients believe that the BOQ as an additional expense to them with no benefits to their projects (Jackson, 2011). However, contradictorily the absence of a BOQ may lead to greater variability, increased risk in estimating and consequently more disputes in construction projects (Davis, Love and Baccarini, 2009).

According to the analysis of expert interview, BOQ is a very important document in construction industry of Sri Lanka, which shows the breakdown of the contract price and can be used as a cost controlling document. According to the analysis BOQ has a good recognition within the Sri Lankan construction industry, since clients has opinions that BOQ can control the cost of their projects. However, in terms of effectiveness and quality of BOQs the participants were not satisfied. In terms of errors all participants accepted that there are errors in BOQs which become very critical in post contract stage. Hence, there is a possibility to reduce the reliability of the BOQ among stakeholders of the project and it affect to the sustainability of the document.

1.2. *AIM AND OBJECTIVES OF THE RESEARCH*

The aim of this research was to minimise BOQ preparation errors that are being made in BOQ preparation stage. In order to fulfill the aim, four objectives were established as follows;

1. Identify errors that are being made in preparing BOQs, from the point of view of Quantity Surveyors
2. Identify causes for errors that are being made in preparing BOQs
3. Identify most common errors and effect of those errors to the time, cost, and quality of the project
4. Recommend suitable solutions for eradicate or minimise identified errors.

2. METHODOLOGY

The methodology of this study can be divided in to three stages: The first one was a comprehensive literature survey, second was a semi structured expert interview which consists of gathering expert knowledge and opinion regarding the subject area of the BOQ and identify errors, causes for errors and solutions for errors. Three industry experts were selected for interviews as illustrated in the following Table 1. As the third and final stage a questionnaire survey was carried out in order to rank identified errors, causes for errors and possible solutions for errors. Questionnaires were divided among 40 numbers of quantity surveyors having both consultancy and contracting experiences and there was an 85.71% respondent rate.

Table 1: Details of the Respondents of the Expert Interviews

Interviewee	Experience	Degree Holder in the Field of QS	Chartered Member	Current Designation
Respondent 1	20 years	Yes	Yes	Consultant QS
Respondent 2	15 years	Yes	Yes	Consultant QS
Respondent 3	15 years	Yes	Yes	Contractor QS

Data obtained through the expert interviews were analysed using content analysis. Based on the answers and opinions of the interviewees common errors and solutions were identified. After the identification of errors and possible solutions through the questionnaire survey was carried out among quantity surveyors who have both consultancy and contracting experiences. Errors in BOQ preparation for the inclusion in the questionnaire survey were selected through both literature findings and data collected through expert interviews. Further respondents were requested to indicate whether those errors affect to the time, cost and quality factors of the project. Solutions were only selected from the data obtained through the expert interviews apart from that additional spaces were provided to indicate other known errors or solutions. Figure 1 shows the composition of the errors and solution included in the questionnaire.

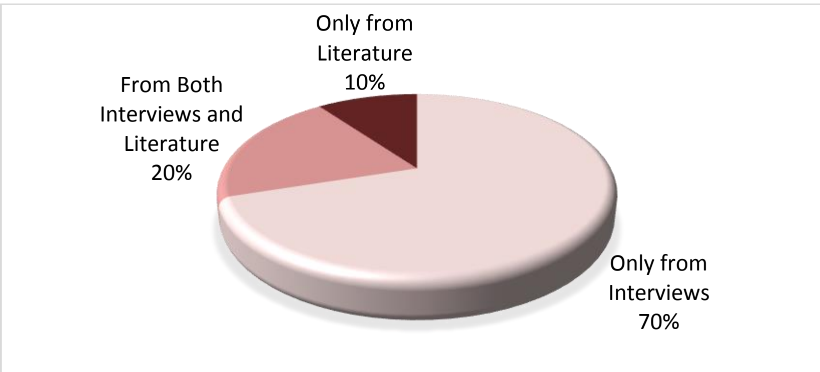

Figure 1: Composition of BOQ Errors Included in the Questionnaire

Data obtained through questionnaire survey were analysed and ranked with the use of Relative Important Index (RII). However, effect of errors to the time cost and quality of the project were analysed by using frequency distribution method.

3. BOQ PREPARATION AND ERRORS

3.1. RELATION BETWEEN ERRORS AND THE PROCUREMENT METHOD

Measure and Pay and Lump Sum are the two most common procurement methods currently practiced in Sri Lankan construction industry. Therefore the study mainly focused on those two methods.

According to the analysis, if there are errors in BOQs preparation under measure and pay procumbent method clients will not get the correct picture about the budget for the project. Therefore they will lead to a change in actual budget. Further, with lots of errors there may be lots of variations. However under the lump sum procurement method at least contractor got the chance to identify and correct preparation errors in the BOQ, but if the errors were not identified it may finally become a loss to the employer or to the contractor depending on the nature of the error.

3.2. BOQ PREPARATION ERRORS

Finally from the literature, expert interview and the questionnaire survey fifteen BOQ errors were identified, and using RII most common errors were identified as shown in following Table 2.

Table 2: Common Errors that are being made in Preparing BOQs

Errors	RII	Rank
Quantity errors	82.67	1
Missed out items to be included	78.67	2
Arithmetical errors	70.67	3
Description errors	62.00	4
Errors in the Provisional Sum	52.67	5
Using irrelevant preliminary items	48.67	6
Errors in the Prime Cost Sum	48.00	7
Errors in unit conversion between imperial and metric	44.00	8
Errors in summery page (Not putting items in correct order)	40.00	9
Wrong headings and sub headings	37.33	10
Inadequate descriptions	3.33	11
Use incorrect preamble notes	2.00	12
Day work bill without clear item coverage	2.00	12
Typing errors	2.00	12
Errors in item numbering and page numbering	1.80	15

The analysis revealed that quantity errors as the major error in BOQs which may include inaccurately added or omitted quantities, depending on the incorrect quantity, BOQ item and the procurement method this may become critical at the post contract stage. Missing items to be included may cause unnecessary variations at the post contract stage. When considering errors within the descriptions there may be a number of errors such as incompatible with drawings and specifications, wrong terms, incorrect symbols like "," or ".", unclear writing styles, typing mistakes. However, finally all these errors will effect to the quality and the reliability of the BOQ, which has been recognised as a useful document within the construction industry all over the world.

Each and Every client of construction projects basically interested on time, cost and quality of their projects, and ultimately they wanted to have a quality output within a short time period and with a lowest cost. However, as per the study it was identified that BOQ errors may directly or indirectly affect to the time, cost and quality of the project. Since BOQ is a document associate with project cost it directly affect to the cost of the project. Moreover there may be some indirect effect, to the time and quality of the project, through errors in BOQ preparation, because sometimes contractors may try to get advantage of those errors, during the post contract operations. Figure 2 shows the findings of the questionnaire survey on the effect of BOQ errors to the time, cost and quality of a project.

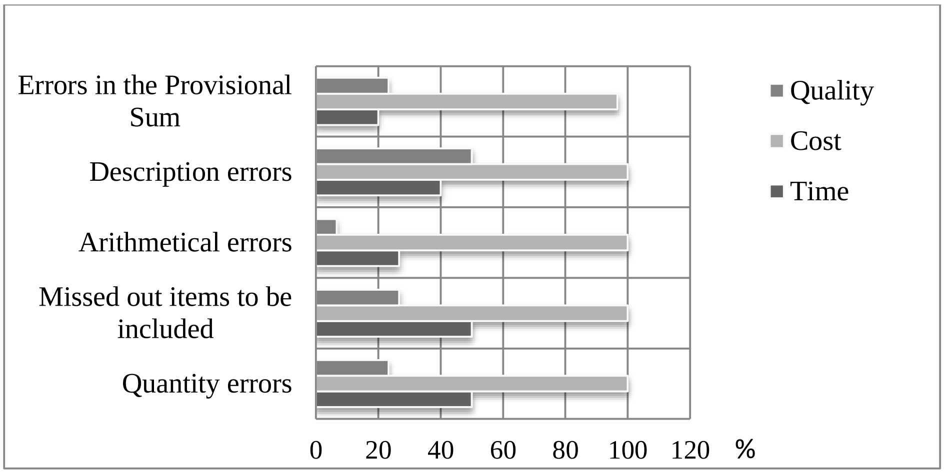

Figure 2: Five Most Common Errors that are being made in Preparing BOQs and Effects of Them to the Time, Cost, and Quality of Projects.

3.3. CAUSES FOR ERRORS THAT ARE BEING MADE IN PREPARING BOQS

The study identified several causes for errors that are being made in preparing BOQs. However, not following a proper standard method, use inexperience persons in the preparation process, and relying strongly on computers were identified as major causes of preparation errors in BOQs.

The practitioners involved with the BOQ preparation should have a good experience and knowledge and they should have the ability to read and understand drawings and other related documents properly. Further, using a standard document is very important, in Sri Lanka if most of the projects stated the standard method the BOQ is not in accordance with the standard method and this will lead to errors such as double counting and missing items. A standard method will provide a guide to prepare the BOQ. In present computer aided bill preparation is considered to be more common and it may be easy and time saving process. However, it may cause for errors because all the time most of the people rely on the computers and do not check their works, but even with the computers there may be errors. Totally there were ten causes identified which cause to errors in BOQs including the above discussed causes as shown in Table 3.

Table 3: Causes for Errors Being Made in Preparing BOQs

No.	Causes for Errors
1	Not using standard methods
2	Use in experience persons to quantify and prepare BOQs
3	Strongly rely on computers
4	Not understanding the project properly.
5	Less of practical knowledge
6	Not done the check list properly
7	Specification errors
8	Don’t read the drawing properly
9	Not following the proper procedure (studies the drawing, does the checklist and starts the work).
10	Having a limited time and it is the last lap of the process.

3.4. SOLUTIONS FOR MINIMISING ERRORS THAT ARE BEING MADE IN PREPARING BOQS

The aim of this research was to identify and minimise errors that are being made in preparing BOQs in Sri Lankan construction industry. Hence, the study focused on identifying available practical solutions and ranking the identified solutions which would minimise BOQ preparation errors. Solutions identified through interviews were included in the questionnaire for ranking, and other than those mentioned solutions respondents has identified 2 more solutions. All together there were seven solutions for BOQs preparation errors and all those errors were prioritised with the use of RII as stated in Table 4.

Table 4: Solutions for Common Errors that are being made in Preparing BOQs

Solutions for BOQs Preparation Errors	RII	Rank
Use people with good experiences	93.33	1
Use a checker to check the final BOQ	89.33	2
Do the check list properly (T.O. List)	86.66	3
Follow a proper accepted method of measurement	84.66	4
Follow a proper procedure (such as study drawing, prepare the check list, then start to prepare BOQ)	84.00	5
Improve technical knowledge of people involved	3.33	6
Proper co-ordination of taking off team by an experience person	3.33	6

From the results of the questionnaire survey, solutions for BOQs preparation errors were ranked according to the agreement of respondents for provided solutions. Above Table indicates the results of the analysis of solutions for preparation errors being made in preparing BOQs according to that using people with good experience is the most agreed solution by the respondents which having 93.33% of RII value. Further, other stated solutions also have got RII values more than 80% so it can be emphasised that all identified solutions from the expert interviews had highly agreed by the respondents of the questionnaire survey. However, using a checker to check the final BOQ has become the second most agreed solution with 89.33% of RII value, respectively doing the check list (Taking off list) properly, following a proper standard method and following a proper procedure (such as study drawing, prepare the check list, then start to prepare the BOQ) has become to the third, fourth and fifth most agreed solutions, with 86.66%, 84.66% and 84.00% RII values respectively. Apart from that, respondents of the questionnaire survey has identified improve technical knowledge of people involved and proper co-ordination of taking off team by an experience person as another suitable solutions for minimise BOQ preparation errors.

4. CONCLUSIONS

Construction industry is an imperative industry of any country, since it has a direct and significant impact with the economic development of a country. Hence the construction should be carried out in an effective manner. In order to carry out construction in an effective manner contracts between each party become very important and the contract document can be identified as the key document available as the document governing major stakeholders in the construction industry in order to complete the project effectively. The contract document comprises with number of documents related to various aspects required for finalise the construction successfully, and from those documents BOQ is the key document related to the cost of the project, which is a key concerning factor of any employer.

Thus, this research study aimed to identify the common errors that are being made in preparing BOQs in Sri Lankan construction industry, which may affect greatly to the sustainability of the document. Further it identifies causes for those errors and suitable practical solutions for minimise those errors, in order to confirm the sustainability and trust towards the BOQ, as the key financial decision making tool in the construction.

From the available literature it was synthesised that the BOQ has multiple uses during both pre contract and post contract stages especially under the traditional procurement method, but disregarding those advantages there is a decline of the usage of BOQs. Even lot of issues causes for that decline, BOQ errors had been identified as a major disadvantage since it affect to the accuracy and hence reduce the trust of the users. However, the opinions obtained through expert interviews together with the analysis of the questionnaire survey established a proper understanding of errors in BOQs and ways to minimise the errors in order to maintain the quality and reliability of the BOQ as a financial decision making tool in the construction industry of Sri Lanka.

Ultimately it can be recommended that in order to minimisation of errors in BOQ preparation, persons involved in has a greater effect and thus, to have even one personnel with adequate knowledge, skills, and experiences to coordinate the BOQ preparation process may leads to have error free BOQ with good quality. Other than the major recommendation stated above using proper standard documents during the BOQ preparation may leads to reduce the error margin of BOQs.

Finally it should be concluded that BOQ is an important and very useful document for the construction if it is used in an effective manner. However, this research study has identified regarding errors, which is a major shortcoming of a BOQ since it affect to the accuracy. Thus, with the usage of the results of this study, the error margin of the BOQ can be reducing up to a certain extent and increase the reliability upon the BOQ in order to sustain the BOQ as a vital document in the construction industry.

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IMPACT OF AESTHETIC APPEARANCE TO FACILITATE CORPORATE BUSINESS OBJECTIVES IN ORGANISATIONS

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ABSTRACT

Aesthetic appearance is a judgment of value based on the appearance of an object. Shapes, proportions, rhythms, scale, degree of complexity, colours, and illumination are the subject matter of formal aesthetics. Aesthetics appearance is an important field in psychology as aesthetics influences the human mind and can lead to psychological reactions, both positive and negative. Creating an aesthetically distinctive identity of development will become an integrated part of the community because user's state of mind and feeling affected by the emotional elements in design. However, this area has not been addressed in detail. Thus, this research focused to identify and analyse parameters of aesthetic appearance of buildings and their impact towards corporate business objectives of commercial organisations.

The research used case study approach and two commercial buildings were selected as cases. Data were collected using semi structured interviews. Data analysis was done using content analysis. Five parameters were established to analyse the aesthetic appearance. Findings revealed that all forms and elements of aesthetic appearance are full of potentially symbolic meanings and have considerable impact on corporate business objectives. Though, there are considerable aesthetic applications as mentioned above, still there are substantial deficiencies in current practices of adaptation of aesthetical appearance for building design in Sri Lankan context.

Keywords: *Aesthetic Appearance; Business Objectives; Facilities Management.*

1. INTRODUCTION

Creating an aesthetically distinctive corporate identity is an effective strategy for attracting customers (Dell'era and Verganti, 2009). Corporate identity is considered to be an integral part of the corporate brand (Kirby and Kent, 2010). Furthermore, Kirby and Kent (2010) mentioned that effective communication of a brand's identity is critical to achieve intended differentiation. Corporate identity can be transformed in to a powerful force to achieve corporate business objectives (Simpson and Cacioppe, 2001). In this regards, pleasurable space design, proper signage system, coherent theme colours and disability access facilities contributed to facilitate success of business (Sadamura and Zhang, 2009).

Aesthetic appearance of a building is the first opportunity to make a positive impression on potential community and stakeholders. A common concept among many people is that first impressions are very influential (Kirby and Kent, 2010). The exterior appearance of a building, a block of businesses or cluster, silently announces what customers can expect inside (Bastow-Shoop *et al*., 1991). Well-designed building orientation, signage and attractive facade materials are crucial to attract people (Caspari *et al*., 2006). Whether it be meeting new people, or seeing a building for the first time, the initial impressions can be the deciding factor for someone liking it or not (Chan, 2010). For buildings, the appearance can immediately determine if its architectural design was a success or a failure. If a building functions optimally but displeases observers, it is likely to be seen, at least by the public, as a failure (Drainage Services Department, 2006). If the appearance of buildings appeals to the general public, however does not operate optimally, many will still considered it successful (Abu-Obeid *et. al*.,

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2008). Therefore, the appearance of a building is a vital element to consider in design by end user point of view.

Aesthetic appearance possesses the ability to demand attention, make a statement, and make time stand and also can captivate people from all walks of life (Chan, 2010). In turn, aesthetic appearance can give people a sense of familiarity through a connection to time and place. It is revealed that aesthetic appearance helped person to identify with the spirit of the place, and offered him a thorough reminder on their mind.Though it is difficult to objectively assess aesthetic value; it often becomes an important determining factor in overall value of a business (Smith, 2012). However, it has given a little consideration on discussing on impact of aesthetic appearance to facilitate corporate business objectives. Therefore, this research was conducted to fill the research gap by analysing impact of aesthetic appearance to facilitate corporate business objectives by focusing commercial organisations in Sri Lanka.

2. LITERATURE REVIEW

Inspiring and stimulating workplace can be achieved through providing an environment with a combination of the familiar and unfamiliar; natural and hi-tech elements, tactile surfaces, mood-enhancing lighting and sound, standard and unusual furnishings (Dell'era and Verganti, 2009). Generally the shapes, proportions, rhythms, scale, degree of complexity, colour, and illumination are the subject matter of formal aesthetics (Abu-Obeid *et al*., 2008). Corporate name, logo, symbol, typography and colour are the most attractive aspects in aesthetic appearance which helps to build awareness and recognition of the organisation (Kirby and Kent, 2010). Following paragraphs provide explanation on different factors of aesthetic appearance of colour, facade design, logo, layout design, visuals and artifacts and landscaping.

2.1. COLOUR

It is widely recognised that colors have a strong impact on emotions and feelings of human (Mahnke, 1996). Colour as an aspect of emotional language. Research on colour and emotion began as early as the late 1800s and highlighted the emotional connection to colour could be one means to understand individuals' preferences. Mahnke (1996) highlighted that different kinds of emotions such as anger, joy, sad and happiness can be originate based on colours. Furthermore, colours impact on mood and the productivity of occupants in a working environment (Kwallek, 1997). Mahnke (1996) promotes color in-workspace as a way of influencing employees' emotions. Kwallek (1997) emphasises individuating color selection to generate the desired emotional experience. Thus, many studies have acknowledged the power of color, as a design agent, to elicit individual emotions.

Askari and Dola (2009) found that use of appropriate colours for different types of buildings is critical to obtain unique image and identity for a building and to attract customers emotionally. Utilisation of familiarised colours to buildings can obtain potential attraction of people (Sadamura and Zhang, 2009). Usage of inconsistent colours such as pink, yellow and blue tarnished the historical images of buildings while grey and white colours are more suitable (Askari and Dola, 2009). A survey conducted by and Kent (2007) revealed that only 11% of the 1000 office workers were enjoyed working in cream, beige, or brown office environments, while 88% claimed more vibrant colors would improve morale, efficiency, and performance. Moreover survey recognised that 20% would prefer light blue and 13% would select light green while 16% prefer yellow colour in their working environment. As a result, over 60% of British businesses could improve staff morale and motivation by adding color to their work environment (Stoneand Kent, 2007). Sadamura and Zhang (2009) revealed that use of "Fukugin Blue" colour which was very familiar to Japanese people for refurbished new banking establishment was achieved desired customer attraction. Therefore, use of coherent and familiarised colours could help to attract customers easily (Drainage Services Department, 2006).

2.2. FACADE DESIGN

Facade is the face of building which is the most important aspect in a design of a building (Huxtable, 2004). Building facade represents the visual richness and the quality of the building (Askari and Dola, 2009). It provides the connection between inner and outer space of the building (Hayashi, 2004). Facade has become the vital aspect of evaluation of buildings by visitors (Huxtable, 2004). The quality of a building front is a major determinant for a customer, particularly a new customer, and should not be underestimated (Bastow-Shoop *et al*., 1991). Good exterior aesthetic presentation attracts attention, creates interest and invites the customer into the business. Building facade imposes considerable impact on the building image hence public’s mental presentation of buildings is mostly based on facades (Imamoglu, 2000). The exterior presentation can offer a conservative, progressive, or discount image to the customer (Bastow-Shoop *et al*., 1991).

Brick, stone, precast concrete, glass and metal is used as common facade designs materials. However in contemporary trends, people use natural materials such as stone, wood or metal to make them the dominant or complementary finish of the facades (Kirby and Kent, 2010). According to Coeterier (2002) stone is a durable traditional building material finishes which will provide facade a dignified and elegant look. According to Brown and Gifford (2001) there was growing interest for use of highly glazed facades in commercial buildings and open type glazed facade system provides unique aesthetic value.

Brown and Gifford (2001) stated six cognitive factors of clarity, complexity, friendliness, originality, ruggedness, and meaningfulness as the predictors of a building facade evaluation. The criteria for the attractiveness of a building facade are introduced as colour, material and proportion (Coeterier, 2002). The images of building facades are mostly represented through their visual elements such as style, volume, material, shape, forms and surfaces (Huxtable, 2004). Askari and Dola (2009) revealed that style, shape, decoration and material of building frontage as the most important factors in evaluation of building facades while dimension of building frontage and texture of building frontage as less importance visual elements. Therefore, it is vital to have an attractive and hospitable facade to the building.

2.3. LOGO

Logo is a symbol or emblem used by enterprises, institutions and organisations to promote public recognition (Saleem, 2012). Logos are either purely graphic or are composed of the name of the organisation. In simpler terms, a logo can be defined as the face or brand of a business (Saleem, 2012).Barber (2013) stated that a business is not worth without having unique logo. Logo should be consistent with organisation type, not based on individual preference. Symbols colour and design of logo should consistent with corporate themes and objectives. Priority should be given to consumers or stakeholders of the organisation (Heilbrun, 2002). Thus, designing a logo need to consider audience’s perspective along with organisational taste.

Logo has power to stimulate reminder on community about product or business and provides a professional and genuine feel to business (Barber, 2013). Furthermore, already established brand identity helps in expansion of business to newer domains as well (Kirby and Kent, 2010).As mentioned earlier, first impression which a business creates among its customers is the best impression (Caspari *et al.*, 2006). People remember more of what they see than what they hear or read. Therefore, logo has an ability of generating reminder and recollection in the minds of the customers (Saleem, 2012). Therefore, logo needs to be creative and attractive as dull and boring logo will not provide a welcoming feeling to its customers (Saleem, 2012). Complex and complicated logo designs leads to generate frustrate attitudes on people mind (Barber, 2013).Considering these concerns, logo can be used as a good device to represent a business and helps business to be memorable among customers.

2.4. LAYOUT DESIGN

An effective way of attracting customers to a business organisation is by having good layout in the built environment, both exterior and interior (Bastow-Shoop *et al*., 1991). Layout is the sizing, spacing, and placement of contents in design (Arfa Technologies, 2013). The basic objective of layout is to ensure a smooth flow of business activities, material and information through a system. Attributes of an effective layout includes balance, emphasis, proportion, rhythm, colour, lighting and harmony (Kirby and Kent, 2010). Ease of future expansion or change, flow of movement, materials handling, output needs, space utilisation, shipping and receiving, ease of communication and support, impact on employee morale and job satisfaction, promotional value and safety are the factors need to be determine in layout and design of built environments.

Well-designed layout designs are essential for a consistent theme and to help the customer find advertised items (Kirby and Kent, 2010). Effective layout is crucial in helping users find quickly what they are looking for, as well as making the appearance visually appealing. Effective layout can make the difference between designs that users immediately understand and those that leave users feeling puzzled and overwhelmed. Indoor displays should attract attention, create interest and invite people into the business to purchase goods. According to Bastow-Shoop *et al*. (1991), there is less than eleven seconds to accomplish this, as that is the average amount of time an individual will spend looking at a window display. Furthermore, Kirby and Kent (2010) found that a customer will be attracted to a display within three to eight seconds; that is the time a customer spends to determine interest in a product. However, according to Saleem (2012), it should be careful not to crowd too much merchandise into a window, as customers find it difficult to determine the message and what items are being promoted. Therefore, properly lighted window displays can help sell specific products or ideas that promote the brand image (Kirby and Kent, 2010).

Some effective displays are created by suppliers or brand-name manufacturers, while others are developed from scratch. Layout and design is an important component of a business's overall operations, both in terms of maximising the effectiveness of the production process and meeting the needs of employees and therefore, it is critical to have a properly designed built environment.

2.5. VISUALS AND ARTIFACTS

Simple, brief, well designed, well lettered and easy to read signs, visuals and artifacts will convey a feeling of welcome (Bastow-Shoop*et al*., 1991). They should be unique, noticeable and readable. Furthermore, signs are ideally supposed to convey information as guidance to the user in a simple and clear way, such as directing the user within the surrounding space, or how to use the equipment or services on offer (Sadamura and Zhang, 2009). Elegant and expensive sign materials may suggest luxury goods and services. Signs may also be used to target a specific market segment such as youth, women, senior citizens or singles (Bastow-Shoop*et al*., 1991).

A marquee can be used to announce a change in seasons, a special event or a promotion (Kirby and Kent, 2010). Further, the top of the permanent canopy provides an opportunity to showcase seasonal displays or special promotional banners which can be hung from flagpoles, projected from the building or hung flat against the exterior (Saleem, 2012). The design concept used on the banners will be more effective if an attempt is made to carry the theme colours and graphics.Signs with unlit or missing light bulbs, flaking or faded paint, or cracked and peeling backgrounds can damage the overall built environment image (Bastow-Shoop*et al*., 1991). A shabby or dilapidated sign implies lack of concern with the business image, and a sloppy, poorly managed business. Signs should be well maintained, and painted every three years or sooner if they weather or fade. Therefore, properly designed visuals and artifacts will promote the business which attracting customers.

2.6. LANDSCAPING

The landscape can provide viewers with satisfactions such as orientation, movement, stimulus, delight, and interest (Aburto *et al*., 2002). Plants (especially flowering bedding plants) enhance the overall look of the built environment, and also add to its positive reputation in terms of beautifying the community (Aburto *et al*., 2002). Attractive natural landscapes in buildings will increase the employee production by reducing stresses and toxic gases. Living plants bring forth the freshness of outdoors, boosting morale and productivity of employees and visitors alike in built environments (Rasuli, 2013). Further, it was revealed that impact of green vegetation and landscaping features towards taking people’s preference attitudes and goodwill to the building (Drainage Services Department, 2006). Thus, green roofs are considered as one of sustainable landscaping options with a profound visual impact (Jungels *et al*., 2013).

The essence of good landscaping is simplicity; simple landscape designs that are easy to maintain (Aburto *et al*., 2002). For example, uninterrupted expanses of grass are easier to maintain than areas cut up by several small beds of flowers or shrubs (Bastow-Shoop *et al*., 1991). Planters, flower boxes and plants used in front of a building add to the general appearance, regardless of what type of merchandise is being sold. A cluttered entryway causes shoppers to indefinitely postpone entering a built environment, while an attractive, well designed entrance is inviting to the customer. Suitable selection and execution of landscaping design aids to eliminate monotonous appearance of a building and able to grant pleasant appearance which typically perceive by people (Drainage Services Department, 2006). Appropriate sizes of trees should be selected to soften the monolithic effects of the buildings, fences, and wall and associated structures. Furthermore, climbers, flower racks and other vertical greening can be provided to beautify the external walls of building and to keep it cool.

3. RESEARCH METHODOLOGY

This research was intended to analyse the impact of aesthetic appearance to facilitate corporate business objectives. Researcher carried out a background study on a broader perspective to familiarise with the subject area referring journal articles, books, reports and other publications. Then researcher gradually extended the background study and a comprehensive literature review was developed to identify parameters of aesthetic appearance while holding the focus on research problem. Since the study is of exploratory nature and requires an in-depth understanding qualitative research approach has been identified as more suitable. Feagin *et al*. (1991 cited in Tellis, 1997) identified that case study is an ideal methodology when a holistic, in-depth qualitative investigation is needed. Thus, this study adopted case study research approach to identify impact of aesthetic appearance on assisting corporate business objectives.

Identification of unit of analysis or the case is of foremost importance to any research design and it is linked with the way of research problem is created (Yin, 1994). The unit of analysis in this research was a commercial building of a multi chain organisation based in Sri Lanka which designed based on same aesthetical concept in order to assist core business by generating own culture of establishment based on brand. According to Yin (1994), number of cases in case study could vary from one to eight as per the nature of the research. Two numbers of cases were selected for this study from two difference fields of businesses. One case was from banking sector which is a branch of a local bank of a multi chain organisation. Other case was from automobile sector which is a branch of foreign multi chain organisation. Both commercial buildings were designed based on the same aesthetical concepts of their brand.

Semi structured interviews was selected as the most reachable and reasonable data collection technique. Noor (2008) stated that, semi-structured rather than structured interview enable sufficient flexibility to approach different respondents differently while still covering the same areas of data collection. Semi structured interviews were conducted among corporate directors, senior managers and maintenance engineers of each organisation. Collected qualitative data was analysed using content analysis technique to gain outcomes of the research.

4. RESEARCH FINDINGS

Case Study Description

Two cases (Case A and Case B) were selected for data collection; and details of these cases are given in Table 1.

Table 1: Case Description

	Case A	Case B
Organisational Type	Automobile company	Bank
Location	Colombo	Colombo
Description	Automobile manufacturing and dealing company, over 200 subsidiaries around the world	Reputed banking establishment in Sri Lanka, 210 subsidiaries
Type of Customers/ Occupants	Local and International customers	Tenant employees and clients
Awards	Prestigious automobile brand [2006]	Best banker [2000/2013]
Business Origin	International	Local

4.1. CASE A

- ***Exterior and Interior Colour of the Building***

Company theme colours have been selected for exterior and interior of the building as it can have a strong impact on emotions and feelings of both customers and employees. Selection of theme colour of company was derived on the emotional impact of people. It has used grey colour as background while using orange colour for name plate of the brand. Orange is a warm and inviting colour, it is both physically and mentally stimulating and it gets people think and encourage socialisation. It is a colour that is dignified, conservative, and carries authority. Gray is the colour of intellect, knowledge, and wisdom. Grey and orange colours have been used as theme colours of business to emphasis the brilliancy of brand and the uniqueness of business culture. Orange and grey colours which have been used provide a unique and identical image of the business and attract customers. It is believed that the colour combination used enhance productivity of occupants as it energises them. Moreover, theme colours of a business can emphasis the business concepts and values. It has identified that colour has ability to create significant impact on corporate business objectives in terms of creating a unique image and brand identity of the company.

- ***Building Shape***

Case A is a rectangular shape building cylindrical shape in one end similar to the mother company in a foreign country. Mainly building shape has been designed enabling more space for business functionality. As car showroom being the most important aspect in the building, that shape optimises the space at car showroom area. More space was available at front showroom to maximise the display capacity of vehicles. Moreover, building shape was designed in a way that all the vehicles in the showroom could viewed by the outsiders through gased facade of the showroom. Unlike other commercial buildings considerable attention has been given to building shape as more space is required to move vehicles. In addition, operational areas were designed enabling employees having freedom and physical convenience in spacey working environment rather than working in confined spaces. Thus, building shape enhances the business functionality, employee productivity and customer attraction.

- ***Facade Design***

Case A has considered facade design as critical factor as it is the face of the building and it has the ability to signify the quality and visual richness of the business. It has a unique exterior facade design as in all other subsidiaries as similar to the view of its Mother Company. It is believed that representing the mother company will ensure the confidence among customers. Moreover, it can easily attract foreign customers who were already familiarised with the company brand. Grey colour has used for the curtain walls of exterior facades of building as theme colours of business to express the brilliancy of brand. Fully glazed façade of the showroom invites customers by demonstrating the vehicles available with them. In addition fully glazed façade provides unique aesthetic value to the building. Entrance has designed in a way to give welcome image to customers by designing double height roof entrance at the front side of building. It provides a hospitable feeling while showing the dignity of the business. Facade design in Case A was based on advertising purpose and customer attraction. Facade design affects the space requirements of business functions. Facade design is a public presentation of a business which could attract customers.

- ***Logo***

Logo acts as an element which contribute to establish own organisational culture. Logo of Case A was based on the coat of arms of Free People's State of Württemberg of former Weimar Germany. Logo was composed using a graphic and providing the company name on the top of the logo. Colours of the logo were based on the theme colours of the company. Location of the logo has decided according to the corporate guideline and concentration has given to provide clear vision. Logo was placed on a tower post which provides a clear view to a person away from about 200 feet, which is the distance required to stop a travelling car of 40 miles per hour. According to corporate guideline logo must attract attention in less than 10 seconds. Furthermore, company desire that logo will communicate quality of brand while upholding brand culture. As it is a quite exceptional logo has an ability of generating reminder and recollection in the minds of the customers. Logo contributes to generate the brand identity of company in worldwide. Thus, logo is considered as most critical parameter which impact on corporate business objectives.

- ***Layout Design***

The purpose of layout design is to develop desire for the merchandise, display what is available, and persuade customers. The percentage of purchase decisions may vary by design of commercial built environment. Case A consists of well-established corporate guidelines for interior layout design. More consideration has given for the showroom area in order to provide attractive atmosphere and convenient layout design for customers. Interior layout was designed considering the aspects of balance, proportion, rhythm and colour. Special consideration was given to provide adequate space for movement of vehicles. Attractive furniture arrangement has been placed in the showroom area in order to provide pleasant and peaceful feelings for customers.

Interior layout design is important to provide good customer service while enhancing the productivity of employees. However, less consideration has been given to layout design in the office areas, as their key concern is on showroom area. Office areas should be designed comfortably considering on employee ergonomic issues. Proper interior space management assists to enhance effectiveness and efficiency of employees by providing a comfortable working environment.

- ***Visuals and Artifacts***

Visuals have used on customer area to maintain brand identity on customer mind. Theme and image presented on the exterior have been carried throughout the interior of the building to provide consistency for the customer. The purpose of interior display is to develop desire for the merchandise. Visuals have been based on newly designed high quality vehicles and those are frequently changed addressing new products. In automobile design sections some visuals and artifacts have been used to provide stimulation for innovative thinking of employees. Those visuals act as media to communicate new products to the customer. Especially designed visuals and artifacts have a possibility of improving productivity. Therefore visuals and artifacts have high impact on customer attraction and productivity of employees.

It is important to pay more attention on placement and location of visuals and artifacts. It was identified that some placements have disturbed the visual richness of exterior facade which some have disturbed the attention of employees. Therefore, it is recommended to distinguish suitable areas to display visuals and artifacts. Attractive visuals and artifacts with proper placements will offer a feeling of welcome for customers.

- ***Landscaping Designs***

Less concentration has given to landscaping designs of the building. However, it would create a pleasant and attractive view if landscaping have used. Landscaping provides economic, environmental and life style benefits. It would help to create a fresh and delight feeling among customers and occupants. Landscaping designs can enhance the viewer satisfaction, delight and interest and provide a pleasant visual image.

4.2. CASE B

- ***Exterior and Interior Colour of Building***

Case B was designed with an extremely attractive colour scheme that perfectly incorporated with company principles, making it appear to be very welcoming and appealing to its consumers. Grey and orange colours have been used prominently as they are the theme colours of business. Orange is a warm and inviting colour, it is both physically and mentally stimulating and it gets people think and encourage socialisation. It is a colour that is dignified, conservative, and carries authority. Gray is the colour of intellect, knowledge, and wisdom. Theme colours have derived based on the concept called Bank for Nation's one of their religions. Banks are functioning on buildings which are owned by them as well as lease hold buildings. The exterior of buildings use combination of orange and grey colours in both types of buildings. In lease hold buildings' interior walls are painted in white colour while combination of orange and grey is used for interior walls of own buildings. It is believed that use of theme colours in the building helped to represent uniqueness of the bank and easy identification among other buildings. Colour combinations which have been used avoid adverse visual effects and enhance the productivity of the employees. In addition these colours invite customers inside and make them more active and energetic. Therefore, colour can affect the productivity of employees. Exterior and interior colours of the building have used effectively to enhance business functionality.

- ***Building Shape***

Buildings which are owned by them are designed to have a unique shape among all branches. However, for lease hold buildings bank identity is developed through own modifications. Case B was designed and constructed by one of Colombo's oldest and most recognised architectural companies. Building shape was designed considering business functionality, energy efficiency and its visual impact on its surroundings. Building has used a rectangular shape allowing more space for business functions while optimising use of day lighting. Rectangular shape has enabled more space in customer lobby area. Thus, it minimises congestions and facilitates free movements to its customers. Another advantage gained by the rectangular plan was it got easily furnished by rectangular furniture. In addition, it provides easy parking facilities to customers at banking premises. Rectangular building shape facilitated Case B to optimise its business functions.

- ***Facade Design***

At the first glance anybody will notice facade of the building, it acts as communication media between bank and people. Building has opened up in the front to ensure appeal and attraction to all its consumers right from the start. The glass front opens the interior of the bank to the outside in an eye catching way, enabling customers to see everything that is going on within the bank. This is to create a sense of transparency at a very basic level. Glassed front view consists of one-way stickers which uses for advertising purpose. Cladding wall system has been used with combination of orange and grey colours for exterior facade in order to provide identity of the bank. The unique facade of the building, decked with the bank's signature orange and highlighted with grey panelling, takes a step away from the more traditional branches which were located across the island. Facade design of the Case B helps to attract customers.

- ***Logo***

Logo of the bank is a filled pot having name in all three languages of Sinhala, English and Tamil. It represent symbol of prosperous. It says bank will provide greater banking service to nation and desire to grant prosperity to the employee as well as customers of the company. Logo of bank is the most critical factor which stimulates brand identity on people about bank. Furthermore, logo has been able to develop own culture to the bank and it has derived focusing the people in Sri Lanka. Location has decided to provide clear and comfortable vision to logo by people. Logo is placed at the middle of front view of the building to ensure the clear vision. A clear vision has been provided to the logo to represent the business to customers. In addition it will help to promote the public recognition. It helps to attract customers for new domains of business expansions. Logo is key factors of aesthetic appearance which generate brand identity and promotes public image.

- ***Layout Design***

It was a complex task to design interior layout of the building as it was required to meet various local and international consideration. To obtain the desired layouts, the initial layout has been moderated few times. In interior layout special consideration was given to the lobby area to provide convenient banking transactions. In the lobby area adequate space was to avoid discomfort of customers even in peak hours. Interior layouts have been designed to reduce the movement distance of customer as much as possible in order to provide quick and quality service to them. Separate cubicles have been provided for prawn and credit transactions in order to provide adequate privacy for customers. In those sections one way stickers are pasted on glass in which outside people will see advertising or promotional display while people who inside can see outside. The bank was keen on making sure that several of their key organisation philosophies were highlighted through this building. Thus, it has used attractive interior arrangement in order to provide pleasant feeling for customer. In addition, interior space have been arranged to provide a comfortable and productive working environment for employees who are dealing with prolonged repetitive work. Layout of the building designed in a customer oriented manner as they believe the differentiation in the banking industry is not really in the products they offer but in the service. Interior layout assists customer convenience and employee productivity while attracting new customers.

- ***Visuals and Artifacts***

Case B has used visuals and artifacts to provide messages on new promotions of the bank to customers. Banners and stickers have been used in customer area to maintain brand identity on customer mind. It was ensured that those are simple, brief and customers can easily read within few seconds. All those were hanged on eye catching places and used all three languages of Sinhala, Tamil and English. Usually one set of visuals and artifacts were only focused on children, youth, women or senior citizen. In addition, framed pictures have been placed in customer lobby area to provide a homely image and visual satisfaction. Therefore, visuals and artifacts can be effectively used to attract customers which conveying commercial notices.

Visuals and artifacts can stimulate unique brand identity on customers. However, as identified some of the banners and stickers were not represents the unique identity of the bank. Therefore, it is important to design all the visuals and artifacts in a consistent format, highlighting theme colours and logo. It should be ensured that all these visuals and artifacts have elegant and orderly designed to uphold the good will of the organisation.

- ***Landscaping Designs***

It was believed that landscaping could provide enthusiastic and pleasurable feelings for its viewers. Landscaping has been used at car park area and some flower plots have been kept inside the building. Interlocking pavement blocks have been used for the entire car park area which offers durability, life-cycle and aesthetics. However, it was identified that less consideration have been given to landscaping. Properly designed landscapes including more natural plants will provide pleasing atmosphere for its customers as well as employees. In addition, landscaping can be used as a tactic to enhance the beauty and attractiveness of the bank.

5. DISCUSSION

Aesthetic appearance can be considered as everything the customer sees, both exterior and interior which can create a positive or negative image of a business. It was identified that interior and exterior colour of the building contribute to create unique image and brand identity among customers. In addition to that colour can affect the productivity of employees. Moreover, theme colours of a business can emphasis the business concepts and values. This is more alike with literature findings where researches done by Askari and Dola (2009), Mahnke (1996) and Kwallek (1997) revealed that colours in building is critical to obtain unique image, brand identity and it affects the productivity of employees.

Findings showed that the properly designed building shape enabled ease functionality of business by providing adequate space. Moreover, it facilitates to create a welcoming image to the customers and visitors. Façade design of the building is the public presentation of the business. It shows the visual richness of the building. Similar findings are indicated in the literature. For an example, Bastow-Shoop *et al*. (1991) conveyed that the quality of a building front is a major determinant for a customer, particularly a new customer, and should not be underestimated.

Logo of the business helps to create and establish own culture among its subsidiaries. It was mentioned by the experts that logo helped to attract customers for new domains of business expansions. For instance, Barber (2013) clearly indicated that logo has power to stimulate reminder on community about product or business and provides a professional and genuine feel to business.

Layout design of the building enhances the physical convenience for its customers and employees. Properly designed layout designs are created an attractive, pleasant and peaceful environment inside a building. Findings of the researches done by Bastow-Shoop *et al*. (1991) and Kirby and Kent (2010) discovered similar findings. In contrast, Kirby and Kent (2010) identified balance, emphasis, proportion, rhythm, colour, lighting and harmony as the attributes of an effective layout. However, these attributes have not been properly addressed.

Visuals and artifacts act as a communication media for the customers. Finding revealed that attractive visuals and artifacts offered a feeling of welcome for customers. Visuals and artifacts can be effectively used to maintain brand identity among customers. Especially designed visuals and artifacts have a possibility of improving productivity. Research findings of Sadamura and Zhang (2009) and Bastow-Shoop *et al*. (1991) show that visuals and artifacts convey information and a feeling of welcome. Further, banners will be more effective if an attempt is made to carry the theme colours and graphics. However, this was given less consideration and neglected in the local practices.

Arburto *et al*. (2002), Rasuli (2013) and Jungels *et al*. (2013) revealed that landscaping designs enhances the viewer satisfaction, delight and interest and provide a pleasant visual image. Landscaping can provide economical, environmental and life style benefits to the business. However, this was given very little consideration and overlooked the benefits that could be gained in the local practices.

Results of the research showed that aesthetic appearance can create a significant impact on corporate business objectives. Aesthetic appearance is the first opportunity to make a positive impression on potential community and stakeholders. Well-established corporate guidelines for aesthetic appearance can obtain high quality aesthetically pleasant design in particular establishment. According to the results of analysis it has found that aesthetic appearance can be effectively used in order to assist corporate business objectives.

6. CONCLUSIONS

The aim of this study was to identify the impact of aesthetic appearance to facilitate corporate business objectives of organisations in Sri Lanka. Corporate Business Objectives address both economical and non-economical aspects of an organisation. However, maximisation of profit, maximisation of sales, attraction of customers, growth of organisation, enhancing quality of service and enhancing effectiveness and efficiency of employees has been identified as the key business objectives. Two cases were selected for the study and in depth investigation was carried out in order to determine the extent which aesthetic appearance has been influenced on corporate objectives in Sri Lankan context. Building selection was based on buildings, which were braches of a mother company with same aesthetical design as mother building.

A descriptive literature review was undertaken to determine the various parameters of aesthetic appearance. Based on the literature review interior and exterior colour of the building, building shape, facade design, logo, layout design, visuals and artifacts and landscape design has been identified as the most important parameters of aesthetic appearance of a commercial building. A descriptive analysis was carried out among both cases to analyse the identified parameters of aesthetic appearance.

The results of this research shows that colour of the building, building shape, facade design, logo, design layout, visuals and artifacts and landscape design has a significant impact on corporate business objectives such as on maximisation of sales, attraction of customers, enhancing quality of service and enhancing effectiveness and efficiency of employees.Aesthetic appearance is the first opportunity to make a positive impression on potential community and stakeholders. Well-established corporate guidelines for aesthetic appearance can obtain high quality aesthetically pleasant design in particular establishment. According to the results of analysis it has found that aesthetic appearance can be effectively used in order to assist corporate business objectives.

Findings revealed that in designing the layout of the building, poor consideration have been given to employees as their main focus is on customers. However, it is important to provide comfortable and convenient environment for employees to enhance their productivity. In addition, quality and the uniqueness of visuals and artifacts can be further improved to attract more customers. Guidelines should be developed to ensure proper designs and placements for visuals and artifacts. Landscaping can be used more effectively to provide a pleasant and attractive visual environment. Furthermore, landscaping will provide economic, environmental and life style benefits. Therefore, it is recommended to provide more consideration on aspects of aesthetic appearance throughout building life cycle.

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IMPLICATIONS OF INSUFFICIENT AWARENESS OF STATUTORY REQUIREMENTS FOR BUILDING CONSTRUCTION ON CONSULTANT TEAM OF BUILDING CONSTRUCTION PROJECTS

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ABSTRACT

All over the world, the construction industry is inherently subjected to a wide range of statutory requirements which are empowered by various bodies. Though, it is vital to comply with these statutory requirements, the rate of non-conformity is still high in the Sri Lankan construction industry giving rise to punitive actions, cost increases and overruns of project schedules. The researchers assume that either insufficient or lack of awareness of statutory regulations among members of construction consultant team is the main reason for this state of affairs.

The present study therefore focuses on identifying the substantial statutory requirements laid by the Urban Development Authority, Sri Lanka, vis-à-vis building construction in the Colombo Municipal area and their implications for construction consultant team such as Architects, Quantity Surveyors and Engineers, who may be unaware of the existence of such statutory requirements. Accordingly, the research was approached through a document survey and semi-structured interviews respectively. The gathered data was subjected to a content analysis based on the findings of which conclusions were drawn regarding implications and possible strategies to address the perceived problems.

The research reveals that the City of Colombo Development Plan 1999 and its amendment in 2008 with regard to zoning regulations are the twin sources of statutory requirements that are applicable for the Colombo Municipal area. They lay down the zoning regulations, planning regulations, building regulations, and required development guide plans that should be considered by architects and specify the statutory requirements relating to sanitation, mechanical ventilation and air-conditioning that engineers should adhere to when undertaking constructions in the area of the Colombo Municipal Council. The study findings also show how an understanding of Urban Development Authority regulations would help quantity surveyors to discharge their role as a member of consultant team better. On the basis of its findings, the study proposes strategies that could be implemented in order to overcome the identified problem of unawareness of statutory regulations in relation to the members of consultant team.

Keywords: *Building Construction; Colombo Municipal Council Area, Sri Lanka; Design Professionals; Implications; Statutory Requirements; Urban Development Authority.*

1. INTRODUCTION

The construction industry has become the 4th largest sector of the Sri Lankan economy, making up 6-7% of the Gross Domestic Product (GDP) during the past decade (Rameezdeen, 2009). The gradual expansion in the industry has necessitated government intervention in order to regulate it in terms of its performance, standards and the quality of the services that it provides to its customers (Weddikkara and Devapriya 2000). As Kumaraswamy put it, "The construction industry is the locomotive of physical development for the national economy" (cited in Enshassi, Al-Najjar and Kumaraswamy, 2009, p.127). Thus, in India, construction projects are subjected to a many Central and State government laws simultaneously in order to keep the projects both within the budget and in accordance with statutory

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requirements (Construction Industry Development Council, India, 2006). Statutory requirements, according to D. Singhal and Singhal (2012), are those requirements that are applicable in the industry by virtue of laws enacted by the government. In the case of Sri Lanka too, several statutory bodies have implemented numerous construction-related laws and regulations in order to ensure that the performance and quality of the industry reach and remain at certain specified standards. The Urban Development Authority (UDA) is one such statutory body that lays down regulations for the control and maintenance of standards within the Sri Lankan construction industry and it is the responsibility of key players in the construction industry to familiarise themselves and comply with the regulatory environment within which the construction industry operates (UDA, 2011). However, according to the Board of Investment (BOI), Sri Lanka (2013), the consultant team of construction projects have not complied with certain requirements specified for buildings due to lack of knowledge of the regulatory requirements. Such lack of awareness can result in unfortunate consequences: either discontinuation of the project or a higher budget than was anticipated. It is therefore essential for consultant team, as professionals who are responsible for the framework of the construction project on behalf of their client, to have a sound knowledge of regulatory requirements.

Therefore, the present study focused on identifying the construction laws and regulations imposed by the UDA that have a bearing on constructions in the Colombo Municipal Council area and their implications for construction consultant team who may lack awareness of these statutory requirements.

2. Relevance of the Research

Although studies have focused on the fees and delays imposed on design professionals on account of the statutory requirements of governing bodies, equal attention has not been paid to the implications in terms of time, cost and quality that might be the result of lack of awareness or knowledge of such rules and regulations on the part of consultant team relating to the design and structure or even output with respect to the product's performance, all of which in turn run the risk of losing the project even at the end of the project's completion. The negative implications to the project arising from the lack of knowledge of statutory requirements by design professionals may not be confined to time, cost and quality but may extend to the whole built environment. These unfortunate fall-outs may arise owing mainly to either the low attention given to or even ignorance regarding the legal aspects by the professionals who provide consultancy services in the fields of architecture, quantity surveying and engineering to particular building constructions at the outset of the project. The present study therefore focuses on a topic given scant attention in previous studies and addresses thus a gap in the literature by underscoring the need to pay special and urgent attention to the aspect of statutory regulations by design professionals involved in the building construction industry in Sri Lanka.

3. Importance of Statutory Requirements and the Statutory Bodies for the Construction Industry of Sri Lanka

Given the centrality of construction outputs on the quality of life, and in supporting all other economic and social activities, the government of a country pays particular attention to the regulatory aspect of the construction industry (Ministry of Housing, Transport, Water and Works and Minister of Information and Development, Jamaica, 2007). Regulatory requirements are those coming within a legally binding requirement issued and enforced by some government agencies and authorised by applicable legislation (Serocki, 1988). Thus, a government establishes a number of regulatory bodies covering numerous aspects of the construction industry. In the field of construction, these regulatory bodies are entities which impose control on design, construction and operation of a project (Rameezdeen, 2006).

Accordingly, in the case of Sri Lanka, the Urban Development Authority (UDA), Central Environmental Authority (CEA), Coast Conservation Department (CCD), Board of Investment (BOI), Civil Aviation Authority (CAA), Condominium Management Authority (CMA), the Ministry of Defence, various local, urban and municipal councils and other local authorities play the role of regulatory bodies, which impose certain laws and regulations in relation to the construction. Of these, the UDA is a multi-disciplinary organisation engaged in urban planning and sustainable urban development in Sri Lanka while CEA integrates environmental considerations into the development processes of the country (Sri

Lanka Tourism Development Authority, 2013). The BOI, is structured to function as a central facilitation point for investors(Board of Investors,2013), while CCD has been formed to ensure the engineering and management of the coastal zone to facilitate and improve economic development based upon coastal resources (Coast Conservation and Coastal Resource Management Department, 2010). Similarly, CMA has been established for the management and maintenance of condominium properties by amending the Common Amenities Board (Amendment) Act No. 24 of 2003 (Ministry of Construction, Engineering Services, Housing and Common Amenities, 2013). The Civil Aviation Authority of Sri Lanka, on the other hand, which was established under the Civil Aviation Authority Act No.34 of 2002, generates requirements to be complied with regard to the construction of any building, tower or other structure or the making of any alterations to existing building, tower or other structure within the protected areas of the local airports (Civil Aviation Authority of Sri Lanka, 2010). The Ministry of Defence and Urban Development oversees the security clearance of a construction which is planned in a high security zone (Ministry of Defence and Urban Development, Sri Lanka, 2013) while municipal councils and other local level governing bodies set rules and regulations that are relevant to housing activities in their respective areas (National Housing Development Authority, Sri Lanka, 2005).

According to Smith and Sims (1990), all stakeholders in the construction industry are obliged to comply with and give all notices required under the regulatory requirements imposed by government agencies. Given the vast scale of the construction industry and with such an important remit, it is very important that rules and regulations are clearly laid out and obeyed in order to ensure that those undertaking building work do so according to certain standards that are considered reasonable within the industry (Everything Legal Ltd., 2013).

4. IMPORTANCE OF AWARENESS OF STATUTORY REQUIREMENTS

There are many statutes that should secure the attention of a consultant team in the world of construction (Cornes, 1985). Architects, engineers and quantity surveyors, as three main groups of professionals who are members of the consultant team with regard to building and structure constructions should therefore have a sound knowledge of the statutory requirements relating to construction when they divide up their duties in relation to a project.

Cornes (1985) has further stated that while the architect need not have the detailed knowledge of a lawyer, she or he is expected to have a reasonable working knowledge of laws and legislation which affects him/her in the discharge of his/her duties as an architect. Building regulations, for instance, lay down the minimum standards of design that pertain to many areas of the architect’s work, including some aspects of design such as resistance to moisture, structural stability, fire safety, thermal insulation, sound insulation and the height of rooms (Cornes, 1985).

It is obvious that a building or project that is designed disregarding relevant public legislation, by-laws, or the rights of adjoining owners may be banned outright, be open to fines, or incur the risk of demolition orders and/or litigation (Wallace, 1970). Hence, Wallace (1970) further stated that the engineer involved in the project should possess a reasonable working knowledge of laws relating to such matters.

One of the basic attributes that produce a competent quantity surveyor is basic knowledge of national laws and regulations relating to construction (Said, Shafiei, and Omarn, 2010). According to them, a comprehensive understanding of construction laws and regulations comprise should be part of the scope of a quantity surveyor’s characteristics, abilities and knowledge.

However, due to the inadequate or total of absence awareness of such rules and regulations on the part of the professionals relating to design, structure and sometimes the output of the product’s performance, numerous negative implications have arisen.

5. RESEARCH METHODOLOGY

The literature relevant to the research topic was extensively reviewed with the aim of examining the impact of the government on the construction industry, the importance of statutory requirements on construction as well as the important statutory requirements empowered in the case of the Sri Lankan construction industry, the role of the UDA with regard to statutory requirements, and the importance of awareness of the statutory requirements on the part of the design team.

Through a survey which was carried out using semi-structured interviews, the data for the study was collected. In order to capture the data, an interview guideline was prepared. The guideline was divided into three sections as (i) a general introduction to the respondent, (ii) investigation of substantial statutory requirements empowered by the UDA for consultant team, and (iii) implications arising from the lack of unawareness of such statutory requirements on the part of professionals. The interviews were conducted with three key participants in the design: architects, engineers and quantity surveyors and the survey size was limited to 20 interviews as it was saturated at that point. Efficacious responses were obtained from Architects (40%), Engineers (30%) and Quantity Surveyors (30%), who hold high managerial positions in Design side of the construction industry such as former director generals, deputy directors, chairmen of organisations and senior professionals in the field. The experience of the respondents in the construction industry ranged from ten years to over thirty five years and their experience in building construction projects ranged from five years to over thirty five years. Additionally, a document survey was conducted with the intention of capturing missing information regarding statutory requirements empowered under the UDA, which may not have been captured in detail via the interviews conducted. This document survey was basically carried out by referring to the City of Colombo Development Plan 1999, volumes I and II, and its amendment published in the year 2008.

After acquiring free-flowing texts from semi-structured interviews, a code-based content analysis was used for an effective interpretation.

6. RESEARCH FINDINGS

6.1. ROLE OF URBAN DEVELOPMENT AUTHORITY AS A STATUTORY BODY AND ITS REGULATIONS IN RELATION TO BUILDING CONSTRUCTIONS IN THE COLOMBO MUNICIPAL AREA

The UDA is the prime planner and promoter of urban areas to meet the aspirations of urban dwellers whilst improving its quality of life (Weerasoori, 2012). It was established under the Parliament Act no 41 of 1978, to achieve integrated planning and implementation of declared urban areas. It was amended in the year 1979, 1982, 1987 and 1988. The special provisions of this act were amended in the year 1984 while generating the Urban Development Projects (Special Provisions) Act in 1980. However, this Act does not have provisions for the design teams of construction projects though it provides necessary powers to the UDA to create guidelines and apply them in declared areas under the UDA. These guidelines are very important to the design team. The City of Colombo Development Plan which was prepared and gazetted by the Urban Development Authority in 1985 enabled the UDA to implement zoning and building regulations though this was superseded by the City of Colombo Development Plan of 1999and its amendment in 2008City of Colombo Development Plan (UDA,1999, 2011). Further, the Development Guide Plans were a direct result of the establishment of the UDA. While the amendment of the City of Colombo Development Plan in 2008 specifically elaborates zoning regulations for the area, the development guide plans elaborates on some special regulations established for certain areas within the zones of the Colombo Development Plan. Hence, the design team needs to be aware of and adhere to these regulations when carrying out a building construction project in any Colombo suburb.

6.2. *Significant Regulations of the Urban Development Authority that Require Compliance from the Consultant Team*

6.2.1. *Substantial Regulations to be Considered by an Architect*

It was found that the regulations of the Colombo Development Plan are more important to architects than to the other consultants. According to the data gathered, the most important regulations for an architect are the zoning regulations. The other substantial regulation categories to be considered by an architect when designing are planning regulations, building regulations, regulations relating to submission of plans for approval of land subdivisions and buildings, and the Development Guide Plans.

Table 1 gives a summary of the substantial UDA regulations applicable to an architect at the design stage, which were identified through interviews and further enriched via information collected through the document survey.

Table 1: Substantial UDA Regulations to be Considered by an Architect

Section	Provisions under Each Section
Zoning regulations	• Permissible building type • Minimum plot size • Maximum plot coverage • Maximum floor area ratio • Other specifications
Planning regulations	• Street line and building line • Parking and traffic control • Minimum site frontage • Maximum plot coverage • Maximum floor area ratio
Building regulations Space around the building	• Minimum side space (on one or both sides) • Rear space • Overhangs and other sun shading device requirements
Space inside the building	• Minimum width of building • Minimum area of rooms • Minimum dimensions of lavatories, water closets and bathrooms • Minimum height of rooms
Light and ventilation	• Location of source of natural light and ventilation • Sources of natural light and ventilation • Provision of air-well for the purpose of natural light and ventilation of court yards
Other	• Provision of facilities for disabled persons • Provisions for approvals under the Environment Act
Submission of plans for approval of land subdivisions and buildings	• Submission of plan for approval • Preliminary planning clearance • Scales of plans • Particulars to be on plans, site plan and sub-division plans
Development Guide Plans	• Same as zoning • Landscaping

6.2.2. *SUBSTANTIAL REGULATIONS TO BE CONSIDERED BY AN ENGINEER*

The findings of the survey suggest that, broadly speaking, the UDA regulations are not as concerned with the engineers' role as that of the architects. However, it is undisputable that the durability of a building hinges on its structural stability. Hence, the contribution of an engineer is undoubtedly critical vis-a-vis the design. Accordingly, most of the interviewees were of the opinion that an engineer should ensure that the proposed building adheres to the structural requirements at the design stage. Hence, regulations regarding the submission of plans for approval of land subdivisions and buildings are most important to the engineer. Additionally, regulations relating to sanitation, mechanical ventilation, and air-conditioning and building regulations can be considered substantial in the case of an engineer.

Table 2 gives a summary of substantial UDA regulations applicable to an engineer that were identified in the interviews conducted with professionals in the industry which were almost identical to those highlighted in the subsequent document survey.

Table 2: Substantial UDA Regulations to be Considered by an Engineer

Section	Provisions under Each Section
Submission of plans for approval of land subdivisions and buildings	• Particulars to be on plans, site plan and sub-division plans • Structural details and calculation
Sanitation	• Water supply and sewerage • Sanitary convenience • Drainage • Water disposal • Electrical and plumbing work
Building regulations Other	• Provisions for approvals under the Environmental Act • Fire safety
Mechanical ventilation and air-conditioning	• Mechanical ventilation for a residential room • Other rooms requiring mechanical ventilation • Plans for air-conditioning or other ventilation system

6.2.3. *SUBSTANTIAL REGULATIONS TO BE CONSIDERED BY A QUANTITY SURVEYOR*

It was evident that there are no specific UDA regulations to be considered by a Quantity Surveyor since Quantity Surveyors are not all that much involved in the design, their involvement at this stage being limited to preparing the document base of the design. However, it can be said that an overall knowledge of UDA regulations is nevertheless important to a quantity surveyor too and is beneficial to the project. For instance, if an error in the design went undetected by the engineer and the architect of the project, there is still a chance that the QS might detect it and rectify it before it causes irreparable damage to the project if the QS had a proper understanding with regard to the subject. Several interviewees identified parking regulations as something important to a quantity surveyor to a certain extent. For examples, UDA regulations specify the number of parking spots per building as a schedule based on the purpose and size of the building. Thus, if the required parking is not available, the developer has to pay service charges to the government to fulfil the requirement which would affect his or her budget. Similarly, a few respondents claimed that UDA insists on landscaping and planting of trees in certain areas, especially in some development guide plan areas, which would noticeably increase the cost of the project. Consequently, it is essential for a quantity surveyor to have an awareness of these regulations. Table 3 gives a summary of substantial UDA regulations applicable to a quantity surveyor identified through interviews and the document survey.

Table 3: Substantial UDA Regulations to be considered by a Quantity Surveyor at the Design Stage

Section	Provisions under Each Section
Planning regulations	• Parking and traffic control
Development guide plans	• Landscaping

6.3. *IMPLICATIONS FOR CONSULTANT TEAM DUE TO LACK OF AWARENESS OF UDA REGULATIONS*

There are three main categories of implications that the study was able to identify, namely, project implications, indirect implications and other implications.

Project implications are the implications to the project, from the inception to the end of the project and even after completion, covering the whole life cycle of the project. These implications are mainly divided into three categories: time, cost and quality implications.

Indirect implications are those that would indirectly affect the client's or occupant's desired objectives in relation to the project.

Other implications refer to impacts on society owing to the failure to apply the necessary UDA regulations to the project.

6.3.1. *IMPLICATIONS FOR ARCHITECTS*

Table 4 gives a summary of subsequent implications arising from lack of awareness of UDA regulations for architects, which could also be captured through interviews conducted with the professionals in the construction industry.

Table 4: Implications for Architects

Section	Project Implications				Indirect Implications	Other Implications
	Implication	Time	Cost	Quality		
All Sections	• Reform of design	X	X		• Reselling is difficult	
	• Risk of being designated an unauthorized building			X	• Loans are not granted by financial institutions	
Planning a). Street line and Building line	• Demolition		X	X	• No compensation possible from the government	
b). Parking and traffic control	• Rejection of planning approvals	X	X		• Reduction in customer satisfaction	• Traffic congestion
	• Annual payments/fee to government		X		• Reduction in profits	• Road rule violations • Increase in number of accidents

Section	Project Implications				Indirect Implications	Other Implications
	Implication	Time	Cost	Quality		
Zoning	• Penalty		X		• Unpleasant environment to live	• Effects on over all building characteristics of the area • Undesirable surroundings to live in • Discouragement of
	• Demolition		X	X	• Health hazards	• strong economy of the city • Negative impact on the social and cultural aspirations of the community • Physical and social hazards
Building a). Space around building	• Discard project proposal	X	X			
b). Space inside building	• Insufficient space			X	• Occupants feel uncomfortable	
c). Others Provision of facilities for disabled persons					• Reduction in customer attraction leading to reduction in profits	
d). Lighting and ventilation	• Required mechanical lighting and ventilation systems		X		• Unfavourable conditions to work or live in	
	• Becomes a sick building			X		

6.3.2. *IMPLICATIONS FOR ENGINEERS*

Table 5 gives the summary of subsequence implications arising from lack of awareness of UDA regulations by an engineer at the design stage.

Table 5: Implications for Engineers

Section	Project Implications: Implication	Time	Cost	Quality	Indirect Implications	Other Implications
All Sections	• Redesign	X	X			
Submission of plans for approval of buildings	• Resubmission to obtain approvals	X	X			
Building a). Others Fire safety	• Insufficient safety for building			X	• Safety hazards for its occupants	
Provisions for approval under the Environment						• Environment and social hazards
Mechanical lighting and ventilation	• Poor air quality inside the building			X	• Stand the risk of being designated as a sick building [Uninhabitable]	
Sanitation water supply and sewerage Drainage	• Sewerage requirements not up to standards			X	• Health hazards for occupants	• Surrounding buildings affected • Occurrence of floods

6.3.3. *IMPLICATIONS FOR QUANTITY SURVEYORS*

Table 6 gives the summary of subsequent implications that arise from lack of unawareness of UDA regulations by a quantity surveyor for each implication at the design stage. It shows that legal provisions attendant on a quantity surveyor's roles are very few and that the implications arising from a quantity surveyor's lack of awareness of UDA regulation are, therefore, minimal.

Table 6: Implications for Quantity Surveyors

Section	Project Implications: Implication	Time	Cost	Quality	Indirect Implications	Other Implications
All Sections	• Incorrect estimate		X		• Underestimated budget	
	• Re-estimate	X			• Difficulties in arranging finance	
DGP	• Occurrence of variations		X			

6.4. *Strategies to be Adopted to Increase the Awareness of Professionals about UDA Regulations*

Only a few of the respondents addressed the issue of suitable strategies that can be adopted to increase the awareness of UDA regulations among design professionals. The summary of strategies that can be adopted to increase the awareness of design professionals regarding substantial UDA regulations applicable to the design stage as captured in the interviews are given below:

- Organising CPD programmes on UDA regulations

CPD programmes assist in the lifelong learning of professionals. Both the organization of CPD programmes and active participation in such seminars will enable professionals to keep abreast of existing and new regulations with respect to their practice which would in turn help them avoid the implications mentioned in the previous sections.

- Introducing awareness of such regulations via the university curriculum

It is evident that awareness of statutory requirements should initially come from the formal education and training that each design professional has undergone, at university, for instance, which would enable them to enter the industry with a sound knowledge of UDA regulations. It will definitely help towards keeping issues that arise from lack of awareness of such regulations to a minimum.

- Control through professional ethics

Most of the design professionals are members of incorporated professional bodies such as Institute of Engineers Sri Lanka (IESL), Institute of Quantity Surveyors Sri Lanka (IQSSL) etc. When members of such professional bodies practice in their relevant fields, they are bound by the ethics governing their bodies to discharge their duties in the best manner possible. Hence, wrongful practices of design professionals can also be controlled via introduction of professional ethics.

- Education of the public through programmes on the media

There is a responsibility upon the government to educate the public so that, in case of wrongful practices on the part of the professionals, they will lodge complaints with the relevant authorities about them. Educating the public can be done through available media such as the television, radio, print media, etc. Implementation of this strategy would aid in raising the awareness of professionals as well as the general public.

- Encouragement of experts to publish books related to the subject of regulations

Encouraging experts in the field to publish construction-related books is another means by which the gap in knowledge of construction laws and regulations can be mitigated.

6.5. *The Conceptual Model Developed from the Key Findings*

Figure 1 presents the summary of the key findings of the research on substantial statutory requirements empowered by the UDA and the implications arising from not being aware of such requirements by consultant team while also emphasising suitable strategies to be implemented in this regard. It offers thereby a conceptual model to mitigate the adverse implications arising from lack of awareness of UDA regulations by professionals in the industry.

7. Conclusions and Recommendations

The literature review for the study underscores the vital role that the UDA plays as the prime planner and promoter of urban areas in Sri Lanka. The research findings show that the City of Colombo Development Plan of 1999, together with its amendment of 2008, basically governs the statutory requirements relating to building construction in the Colombo municipal council area. The analysis shows why architects ought to be aware of zoning regulations, planning regulations, building regulations, regulations regarding planning approvals and development guide plans in the design stage while it also shows that engineers need to be aware of statutory requirements relating to sanitation, mechanical ventilation and air conditioning. It also reveals why an overall idea about statutory requirements would be desirable in the case of quantity surveyors, enabling them to perform better in the design stage.

The study makes it clear that the implications mainly come under three major categories: implications to the project in terms of time, cost and quality; indirect implications to the client; and other implications to the society at large. These implications could be categorized under each major section of the statutory requirements with respect to each professional separately. The content analysis also yields strategies to overcome the identified implications. Among them, CPD programmes on UDA regulations for industry professionals and introduction of modules to undergraduate education at university where industry professionals are first trained were seen as the best options to overcome the negative implications arising from inadequate awareness. In addition, ensuring minimum standards on knowledge of and adherence to statutory regulations through the concept of professional ethics via the accreditation bodies, education of the general public regarding the existence of such regulations through media programmes and encouraging experts in the industry to publish books on relevant subjects were also identified as the other approaches to minimise the adverse implications. The study advocates the adoption of the conceptual model for use by consultant team members in order to be informed of substantial statutory requirements enacted under UDA and the negative implications arising from lack of unawareness of such requirements so as to pre-empt such situations in the future.

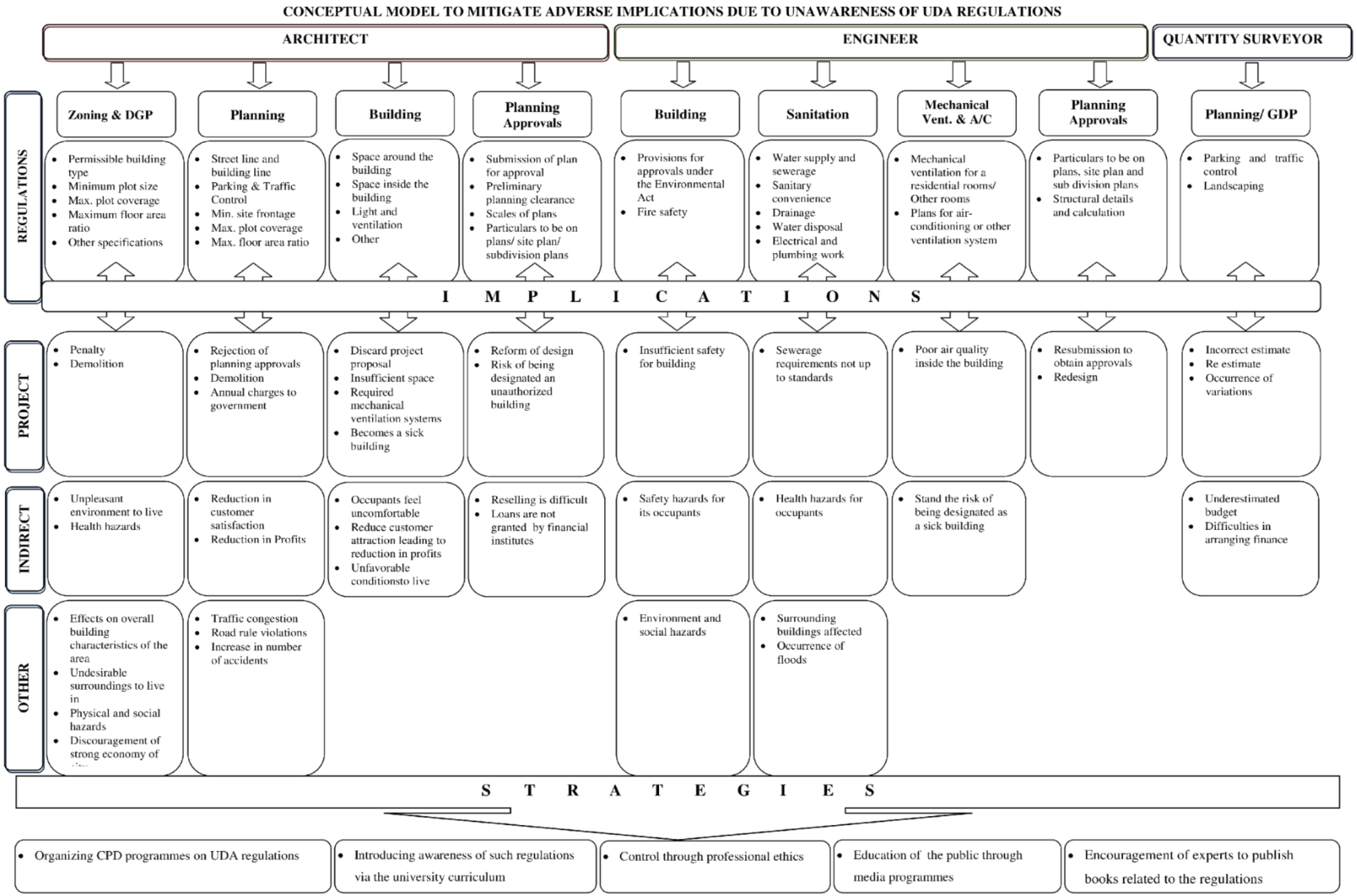

Figure 1: Conceptual Model

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INTEGRATED APPROACH FOR FUTURE SUSTAINABLE URBANISATION

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ABSTRACT

Maharashtra's urban communities are facing demographic, cultural and environmental challenges typical of many other urban communities across India. Increasing population, pressure on infrastructure, increase in migration and changes in social habits has affected many cities of Maharashtra; this change has been accompanied with stigma and neglect, all representative of the relative inflexibility of the urban form. A research study is conducted on sustainable community design and ideal residential housing from a global perspective in order to accumulate new insights and technical expertise that can be utilised in developing future urban settlements of Maharashtra.

The purpose of the study is to create a flexible set of guidelines that account for variability. It allows users to determine intervention points through condition resolution. This study illustrates how stated explicit infrastructure objectives can be translated into design interventions in a variety of conditions and multiple scales. In addition to outlining techniques and intervention points, the study also includes few permutations of how these techniques could be synthesised and employed at the neighbourhood scale.

As part of our overall approach to the study, following principles for design, planning, and development of urban communities are addressed in the study; Integrated infrastructure system, Energy efficiency, Waste water management, Balanced habitat, Sustainable community, etc.

Keywords: *Ecological; Energy Efficiency; Future Urban Communities Sustainable; Integrated Infrastructure Systems.*

1. INTRODUCTION

Maharashtra, a state that covers an area of 307,713 Sq.km i.e. 9.84% of the total geographical area of India, is the third most urbanised state with 45.23% among other major Indian states like Tamil Nadu (48.45%) and Kerala (47.72%) as per 2011 Census of India. Urbanisation is an integral part of economic development. Most modern economic activity takes place in cities, and growth in productivity and income is easier in an urban context. Economic growth influences the urbanisation while urbanisation in turn affects the rate of economic growth (Census, 2011). In many parts of the world, urbanisation is accelerated as a new global economy that is increasingly changing the face of our planet. Managing urban growth has become difficult and complex, leading to one of the most important challenges of the 21st Century (Cohen, 2003).

As the urban population and incomes increase, demand for every key service such as water, transportation, sewage treatment, low income housing will increase five- to sevenfold in cities of every size and shape. And if India continues on its current path, urban infrastructure will fall woefully short of what is necessary to sustain prosperous cities (Mckinsey Global Institute, 2010).

The next few decades will be critical in shaping the urban infrastructure in India as investments flow to cities for expanding their infrastructure networks. India faces a unique challenge of closing the deficit in urban infrastructure and services, while at the same time making a transition to a more sustainable path. However, this deficit may well be a boon in disguise, as it could serve as an opportunity to leapfrog to more sustainable, less energy and resource-intensive forms of infrastructure (Wankhade, 2012).

Understanding the above facts and observations, it becomes necessary for Indian states and cities to develop and adopt innovative methods and technologies that can address the future issues of highly

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urbanised states. This study is attempting towards evaluating the potential of adopting some innovative techniques at the neighbourhood level that can be multiplied to city level and further to the states of India.

2. PROBLEM IDENTIFICATION

Today looking at the state of living conditions in various Indian cities and the different processes that take place in rapidly urbanising cities are causing problems for the natural environment, social and economical conditions of humans, both locally and globally. This problem needs to be addressed by proposing innovative and sustainable solutions. The question is how? How are we going to address these issues on an urban scale to make our cities more sustainable and energy efficient?

3. RESEARCH QUESTION

The most fundamental question that comes to our minds is how can cities be redesigned to make them more diverse, flexible and energy efficient? This further leads to specific research questions such as;

- What are different energy efficient tools of urban designing that can address the issues of water and waste water management of future cities?
- What are alternate and innovative ways to address future energy demands of ever growing cities of India?
- Can systems like biogas plants be used on a larger scale to meet the energy demands?
- Can we integrate various innovative techniques, methods, systems or processes that can be developed into a module at unit level which can be multiplied at neighbourhood level and further can be multiplied at city level to address some issues of future urbanisation?

The exercise would aim at addressing the above mentioned research questions and derive an integrated module for a sample study area.

4. METHODOLOGY

In order to explore different innovative techniques of sustainability for future cities of India, I have considered a sample neighbourhood in a city of Pune, Maharashtra. The approach would be to address the issues at the neighbourhood level, which can be further implemented at city level. The idea is to find the actual implementation of these techniques in an existing city which is rapidly urbanising. The tools used for analysis are simple maps (Map Source: Google Earth) and industry standards with its mathematical evaluation. Following are the sustainability concepts that are tested in the study:

- Grey water management
- Urban bio gas generation system
- Solar farms
- Urban integrated infrastructure system

Figure 1 shows the demarcated neighbourhood in Pune approximately 600,000m^2 area or 0.6 km^2 as a study area.

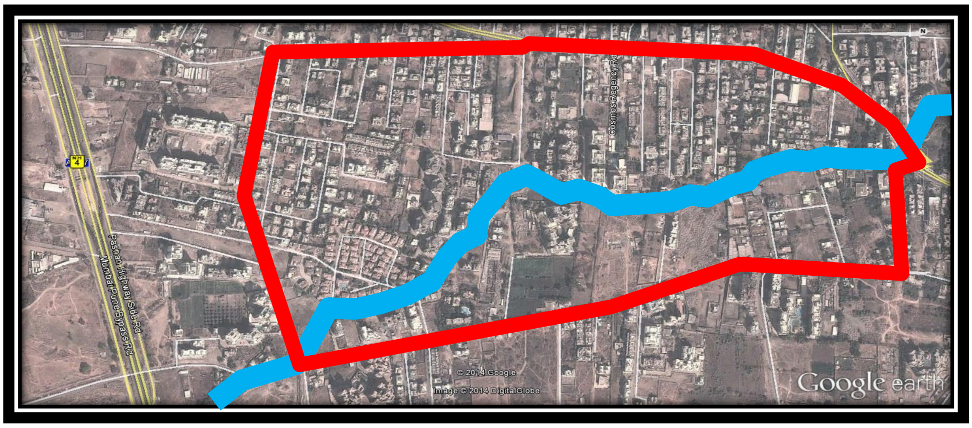


Figure 1: Study Area Demarcation
Map Source: Google Earth

5. GREY WATER MANAGEMENT

Grey water is also known as sullage. It is the wastewater generated from dish washing, laundry, sinks and bathing, for example. It consists of all of the water waste of a household with the exception of toilet water which is called black water (Ecolife, 2011). Fundamentally, the re-use of grey water requires a re-thinking of how we build today. The work begins within the building, separating the grey water from the sewer lines. This may seem like a design problem, but it is also an infrastructural problem. Once separated from the sewage system grey water can be treated naturally or through treatment and can be integrated into gardens, parks and natural habitats (Reschke, 2014).

In the sample neighbourhood shown above in the Figure1, from primary survey we have found that there is a mix of high density and low density developments which have large open spaces in between. Despite the area of green spaces there is a distinct disconnect between the human living environment and the natural. The use of grey water not only nourishes the environment, but enhances the community spaces. By separating grey water and strategically exposing grey water piping at designing interventions, the community can enjoy the sights of the natural environment in the neighbourhood.

5.1. GREY WATER GENERATION

Figure 2 shows the grey water intervention in the sample area. The demarcated area has around 5000 inhabitants, i.e. approximately 1250 households (Pune city sanitation Plan, 2012). As per the standard UDPFI (Urban Development Plans Formulation and Implementation, 1996) guidelines water consumption for domestic use is 200 lpcd (Litres per capita per day) and out of this 80 percent water will generate as sewerage water i.e. grey water and black water together. Out of 80% most of the water is grey water accounting to 57.6 percent that makes the total grey water generated per person per day equals to approximately 92 litres (Pune city sanitation Plan, 2012).

Therefore, in above given Figure 2, total grey water generated would be 460000 litres per day and in a year it would be equal to 16.79 million litres, i.e. a very large quantity of water that goes as waste from a very small area as demarcated in the sample Figure One can evaluate how much water is generated as grey water by the entire population of a city. Out of this 50 percent can be treated and reused further through very simple treatment units because it doesn’t contain any sewage accounting total grey water to 8.39 million litres annually (Reschke, 2014).

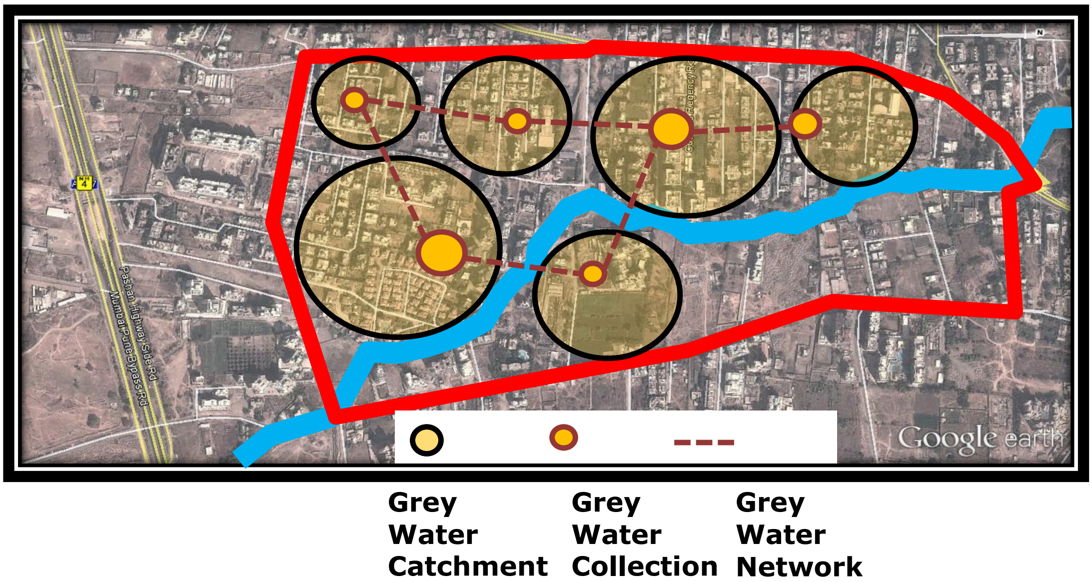


Figure 2: Grey Water Management
Map Source: Google Earth

5.2. *Grey Water Use*

The Figure 2 shows the catchment, collection and network of grey water. This network is developed on the basis of available vacant plots and the distance from households forming a cluster. There is a scope for developing more precise network based on slope, collection capacity, soil strata, etc. This collected grey water can further be treated at neighbourhood treatment plant for reusing. After a little treatment the grey water can be primarily used for flushing our toilets. Everyday an average household flushes 280 litres of clean, treated water that can be easily replaced by the grey water. So the grey water generated from the above sample area can suffice the need of 832 households for flushing their toilets (Pune city sanitation Plan, 2012. Refer UDPFI Guidelines, 1996). The quantity generated by grey water is so large that it can be further integrated and used for certain industries too.

5.3. *Grey Water Intervention*

The above typology of grey water intervention shows how grey water can be integrated from households to a neighbourhood network. High density and building forms allow for the use of grey water for semi-private spaces; i.e. roof gardens and central courtyards. It can provide amenities of healthy lifestyle, reduce energy waste by maintaining cooler building temperatures, promote communal ownership and care for green spaces, demonstrate communal patterns of water usage and collective ecological footprint, may lead to ecologically competitive districts further benefiting the environment.

6. Urban Bio-Gas Generation and Management

Energy is the key input for socio-economic development of any Nation. The fast industrialisation and rapid urbanisation besides mechanized farming have generated a high demand of energy in all forms i.e. thermal, mechanical and electrical. The over exploitations of fossil fuels have been posing serious environmental problems such as global warming and climate change. While we have shortage of energy and more dependent on imports in case of petroleum, we are fortunate enough to be blessed with plenty of natural sources of energy such as solar, wind, biomass, etc. Biogas production is a clean low carbon technology for efficient management and conversion of organic wastes into clean renewable biogas and organic manure / fertiliser. It has the potential for leveraging sustainable livelihood development as well as tackling local and global land, air and water pollution (Ministry of New and Renewable Energy Report, 2011). The biogas solution integrates community level black water collection and processing for the production of biogas. Research conducted by Department of Civil Engineering, Punjab

Agricultural University shows that the sewage waste of approximately 15 persons (or nearly 4 families) could produce enough biogas to fuel the cooking needs of one conventional family.

6.1. BIO-GAS GENERATION

Table 1: Biogas Capacity

Capacity of Biogas Plant (cu.m)	No. of persons may be served	Quantity of Night soil (Kg)	No. of Persons
1	2-3	25	10-15
2	4-6	50	20-25
3	7-9	75	30-35
4	9-12	100	40-45
5	12-15	125	45-50
6	14-17	150	50-60

Source: Department of Civil Engineering, Punjab Agricultural University

The collection and processing systems of a biogas plant can be installed beneath the landscape in an array of density settings. The plot represented below appears on sample site, in various but similar forms, and is well-suited to this form of energy production.

6.2. BIO-GAS NETWORK AND USE

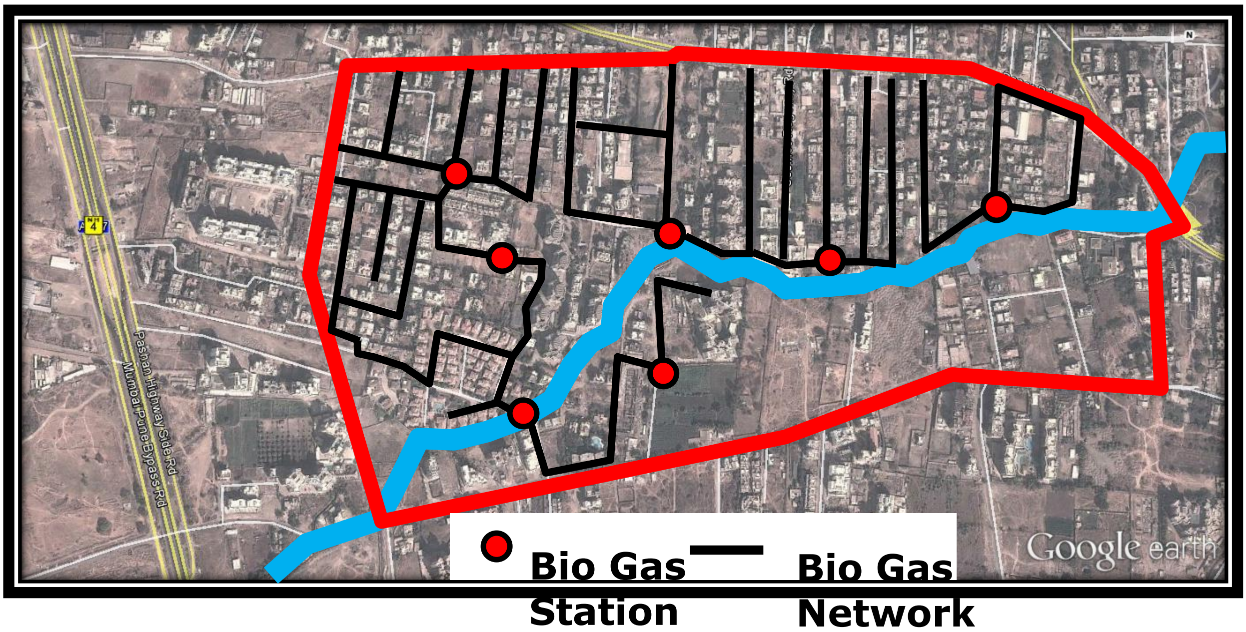


Figure 3: Bio Gas Network
Map Source: Google Earth

Referring to Table 1, for the demarcated sample area and for the population of 5000 (Pune City Sanitation Plan, 2012), we can develop many community level bio gas plants as shown in the Figure 3 totalling to the capacity of 600m^3. i.e. 1500 people can be served with their energy needs. The network shown in the Figure is approximate based on residing population in the study area, it will vary as per the living conditions, type of land use, waste generated etc.

7. SOLAR FARMS

The Shri Sai Baba Sansthan Trust at Shirdi in Nasik District of Maharashtra has world's largest solar steam system. The system is used to cook 50,000 meals per day for pilgrims visiting the shrine, resulting in annual savings of 100,000 kg of cooking gas and has been designed to generate steam for cooking even in the absence of electricity to run the feed water pump for circulating water in the system. The project to install and commission the system was completed in seven months and the system has a design life of 25 years. It is just 180 km from Pune, Maharashtra (Sasikumar and Jayasubramaniam, 2013).

7.1. SOLAR ENERGY AVAILABILITY

As per the Energy Resources Institute (TERI), Maharashtra has a relatively medium range of solar radiation. It is apparent from the map below that the western states have the highest levels of solar radiation, but Maharashtra ranges between 5.4-5.8 kWh/m^2 of the area.

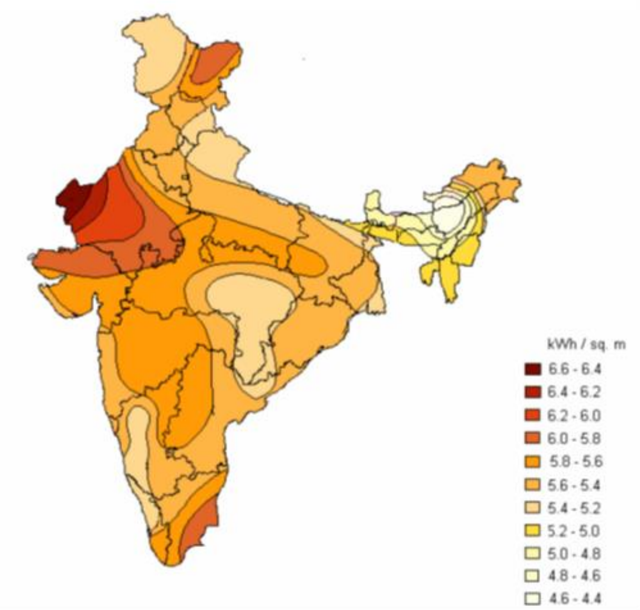
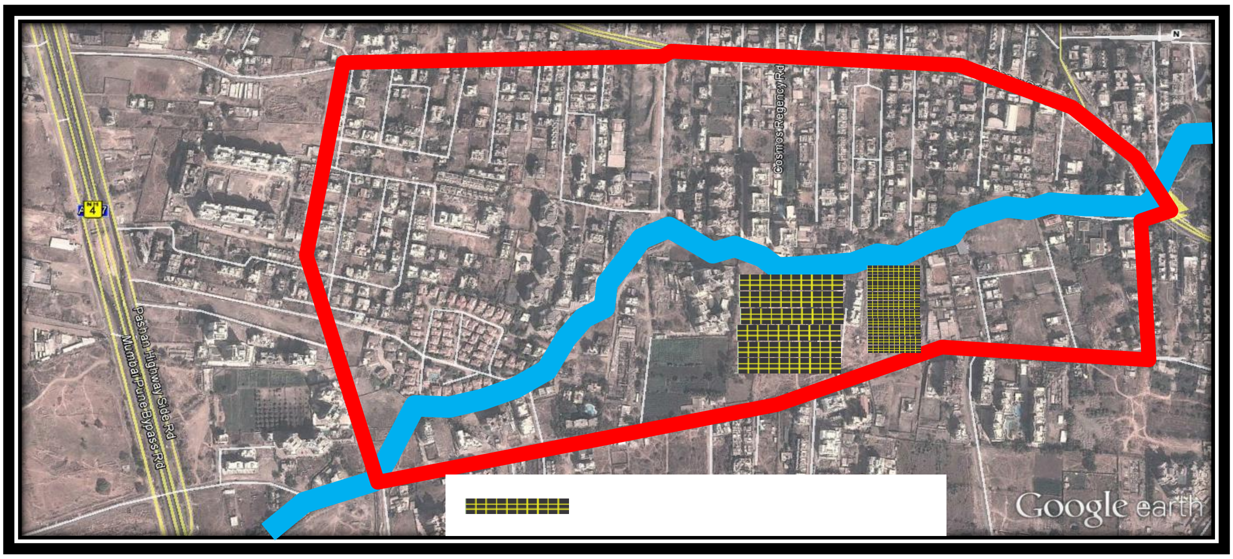


Figure 4: Solar Radiation on India
Source: TERI

Establishing solar farms adjacent to the neighbourhoods or towns they serve, and given adequate sun exposure, can often provide enough electric energy to power a small community. Depending on the size of the farm, excess energy can be sold back to utilities creating shared income for community members. Another benefit of sun farms is that they are highly adaptable to landscape. They can be built on flat sites or into sloped topography. Still, it is important that the photovoltaic panels face south in order to maximise solar gain.

7.2. USE OF SOLAR FARMS



Solar Farm Panels facing South

Figure 5: Solar Farms
Map Source: Google Earth

Solar farms that utilise topography and open space liberate community members from having to install photovoltaic panels on their individual homes, thereby alleviating individual maintenance responsibilities. In above shown Figure 6, in a typical demarcated neighbourhood, we can provide solar farms to meet community level energy needs. In the above case solar farms of approximately 11000m^2 can be provided, that can generate energy up to 66000 kWh in a day. The best location for a solar farm is sites that possess significant south-facing flatlands or slopes that are located at the edge of a community, town, or city

8. URBAN INTEGRATED INFRASTRUCTURE SYSTEM (UNIT LEVEL)

Infrastructure needs cannot be answered separately, integration of all services and utilities result in more efficient use of resources. Therefore, we should look at integrating various infrastructure services at a unit level or a household level and then further integrating with larger grid of community, neighbourhood or at a city level. A community design based on a modular residential block scalable to serve public and town-scale functions can be developed to manage rainwater run-off, grey water, wastewater, energy, and food production. The design is meant to explore a site-level application of the modules, with necessary non-residential systems to support the intervention on the town scale. Figure 6 shows how different energy efficient solutions can be integrated in one system at a unit or household level.

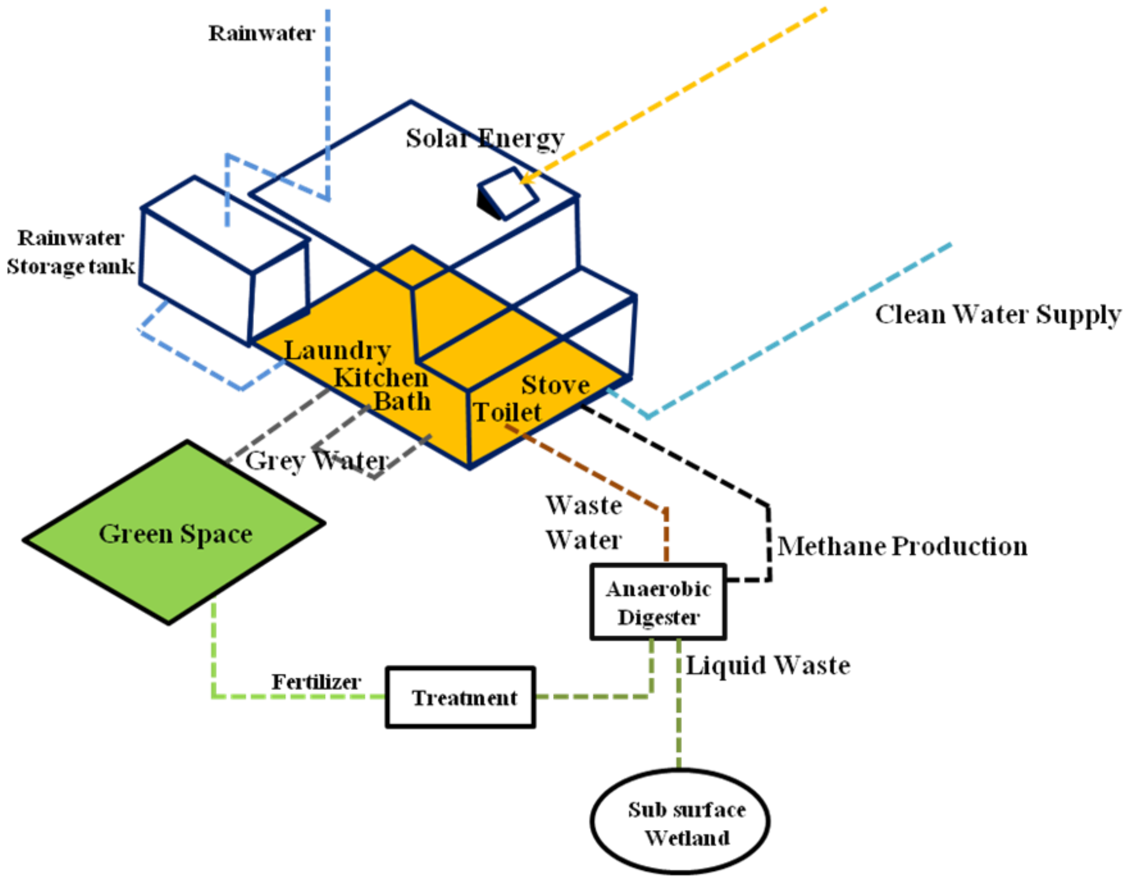


Figure 6: Integrated Infrastructure System

9. CONCLUSIONS AND OBSERVATIONS

All the above techniques can be developed into a standard feasible model and can be multiplied on the city scale to reap larger benefits. Integration potentially allows for more effective and efficient use of resources in order to achieve a given set of objectives. The observations and conclusions made in the study are;

- Grey water management can be used as one of the sustainable tools, which has potential to reuse water and be more efficient. A small neighbourhood of 5000 population has potential to generate 8.39 million litres of re-usable water annually. Grey water design typologies can be developed in different forms. They range in scale and usage from individual yards behind single family rural homes to intensive green roofs and courtyards on urban blocks. Furthermore, they range from individual use to communal use, whereby the exposure of grey water in the streets and in creative spaces for the community will also make the community more aware of their water consumption.
- The ultimate goal may be to create a community that is conscious and sensitive to water consumption; eventually this may even lead to healthy competition among communities. The innovative technique is intended to be used as patterns of use that may be adapted to a variety of different sites and integrated with other complementary city systems.
- Biogas systems has been primarily used in villages but findings in the study like, sewage waste of approximately 15 persons (or nearly 4 families) could produce enough biogas to fuel the cooking needs of one conventional family, is clearly indicating its use on urban scale starting at unit level or neighbourhood level. This system can be efficiently used and managed to meet the energy demands of future cities.
- Solar farms can be installed in open and barren land to tap maximum solar energy. In a state of Maharashtra, electricity of 5.4-5.8 kWh/m^2 of the area of solar panel can be taped.

- A unit level integration of various tools is a first step towards sustainability, but what is important is neighbourhood level integration of these units further integrating with the city's grid to meet energy needs and become sustainable urban form which would be more resilient.

A detailed implementation plan is required with a strong governance model to execute these techniques. It is very critical now to understand the need of urban innovation to sustain in the existing cities and to plan future.

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INVESTIGATING CURRENT CONSTRUCTION WASTE MANAGEMENT PRACTICES IN SOUTH AUSTRALIA: A PRELIMINARY STUDY

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ABSTRACT

The construction industry has been found to be a major generator of waste and the management of construction waste has become a pressing challenge. Due to persisting beliefs that construction waste generation is unavoidable and zero waste is not achievable, researchers have proposed different methods of waste management such as sustainable waste management, integrated waste management, holistic waste management and the waste management hierarchy during past decades. However, when it comes to the Australian context, construction and demolition waste contributes around 25.8% of overall landfill. Therefore, this research aims to identify current construction waste management practices in South Australia in order to find ways to improve them. Sixteen face to face semi-structured interviews were conducted covering major stakeholders in construction projects who had a minimum of ten years' experience in the construction industry and a minimum five years' experience in waste management. The findings reveal that while industry is going through a transition with regards to waste management, waste management practices vary from organisation to organisation. Site space was described as the main limiting factor to implementing onsite waste management practices and it was suggested that waste management should be an important part of project planning. Interviewees indicated that even though there are programmes like Green Star which aim to encourage recycling and waste minimisation; waste management was neglected in the design process. Findings also reveal the urgency of changing attitudes and behaviours towards waste and the importance of considering waste as a resource to encourage improvements in waste management practices. Issues associated with costs and financial management were highlighted as key in determining waste management practices. As such the findings of the study also point to the importance of considering systemic issues of political economy and how they impact on waste management practices.

Keywords: *Construction Projects; Solid Waste; South Australia; Waste Management.*

1. INTRODUCTION

The construction industry is one of the major consumers of energy and natural resources (Merino *et al*. 2010). The industry involves construction, renovation and demolition activities (Yuan *et al*. 2011) which generate a considerable amount of waste annually (Hao *et al*. 2008; Jaillon *et al*. 2009; Manowong, 2012). Yuan *et al*. (2012) also emphasised the non-environmentally friendly nature of the construction industry and its unacceptable level of waste generation. Adverse impacts of the construction industry include land depletion and deterioration, energy consumption, solid waste generation, dust and gas emission, noise pollution and natural resource consumption (Yuan, 2013). As dealing with environmental problems is seen as an increasingly pressing global issue (Hopwood *et al*., 2005), there is a growing focus on sustainability in construction. Due to the emerging trends of sustainability and sustainable development, construction waste management has gained special attention as it focuses on preserving health and the environment, minimising the burden to future generations and conserving resources (Tammemagi, 1999). It is emphasised that sustainable development cannot be achieved without a significant reduction in waste production, along with much increased resource efficiency (Phillips *et al*., 1999). Therefore, this research tried to identify current waste management practices in South Australia to find ways to improve them.

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2. LITERATURE REVIEW

The construction industry has been found to be a major generator of waste and how to manage construction waste in the most sustainable way is a pressing challenge (Manowong, 2012). Diesendorf (2000) considered sustainability as the goal or endpoint of the process of sustainable development. Chaharbaghi and Willis (1999) pointed out that there are different perspectives of sustainable development because industrialists see it as a constraint, environmentalists see it as avoiding catastrophe, politicians see it as a rhetorical device, the media sees it as a commercial opportunity, economists see it in terms of markets and economic development and technologists see sustainable development as a problem they can solve. Sustainable construction is widely considered to be best practice construction since it improves the durability of construction, encourages the use of recycled materials and reduces waste generation (Merino *et al*. 2010). However, as argued by Davidson (2008), there are tensions inherent in the concept sustainable development and the continuous pursuit of growth may not be possible on a planet with finite resources. Shen *et al*. (2004, p.473) defined construction waste as:

> Building debris, rubble, earth, concrete, steel, timber, and mixed site clearance materials, arising from various construction activities including land excavation or formation, civil and building construction, site clearance, demolition activities, roadwork, and building renovation.

Since construction waste can be generated in any stage of the construction project from inception to completion (Spivey 1974 cited in Kulatunga *et al*., 2006), it can be defined as an activity which generates direct or indirect costs, without adding any value or improvement to the product (Serpell and Alarcón, 1998). Construction wastes are comprised of a mixture of inert and non-inert materials (Hao *et al*. 2008; Jaillon *et al*. 2009; Wong and Yip 2004). Environment Protection Regulations (2009) define inert waste as solid waste that has no active chemical or biological properties and is not subject to biological or chemical breakdown. Inert waste includes sand, brick and concrete and non-inert waste includes bamboo, plastics, glass, wood, paper, vegetation and other organic materials (Hao *et al*., 2008). Spivey (1974) categorised construction wastes as demolition materials; packaging materials; wood; waste concrete and asphalt; garbage and sanitary waste; scrap-metal products; rubber, plastic and glass; and pesticides and pesticide containers. Jaillon *et al*. (2009) identified that formwork, packaging and protection, finish work, masonry work, scaffolding, concrete work, material handling and hoarding are key waste producing components in construction. When it comes to design waste, Coventry and Guthrie (1998, p.12) defined it as 'waste arising from construction sites both by acts and by omissions on the part of the designer, including opportunities to reduce waste lost by not using reclaimed materials'. The next subsection describes types of waste management practices and the need for waste management in construction projects.

2.1. TYPES OF CONSTRUCTION WASTE MANAGEMENT PRACTICES

Due to the persistent belief that construction waste generation is unavoidable and zero waste is not achievable, researchers have tried to introduce methods to minimise construction waste generation during past decades (Faniran and Caban, 1998; Kartam *et al*., 2004; Ling and Lim, 2002; Yuan and Shen, 2011). These include sustainable waste management, integrated waste management, holistic waste management and the waste management hierarchy (Chung and Lo, 2003). Chung and Lo (2003) explained that sustainable waste management is focused on environmental desirability, economic optimisation, social acceptability and equity as well as administrative diligence. Integrated waste management combines all solid waste streams, collection and a range of treatment methods, environmental benefits, economic optimisation and social acceptability into a practical and sustainable system (Chung and Lo, 2003, p.121). The waste management hierarchy is based on two pillars of sustainable construction: the minimisation of material usage and the minimisation of the impact on the environment. It includes waste reduction, reuse, recycling and disposal (Peng *et al*., 1997). The waste management hierarchy also includes avoidance of the production of waste along with the treatment of waste to reduce potentially degrading impacts. The 'Three Rs' principle is widely adopted in waste management and it includes reduction, reuse and recycling (Osmani *et al*., 2008) followed by incineration with energy recovery and safe disposal (Al-Sari *et al*., 2012). The Waste Wise Construction

Program Australia and Environment Australia (2000) describe the waste management hierarchy as shown in the Figure 1.

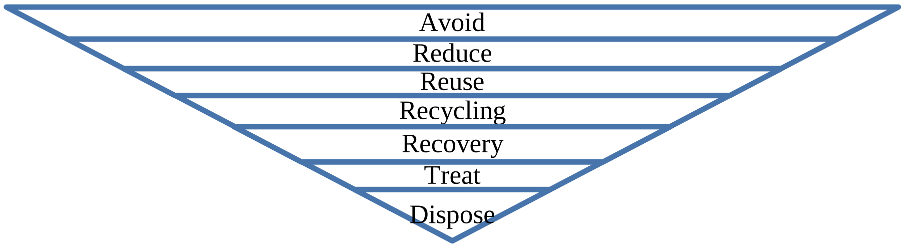

Figure 1: Waste Management Hierarchy
Source: Australian Government (2007)

According to the waste management hierarchy, the initial steps of waste management are to avoid waste generation. Secondly, it is necessary to reduce waste generation and then focus on the implementation of better methods to manage unavoidable waste (Teo and Loosemore, 2001). Researchers found that the most logical and economical way of reducing waste is to reduce waste from its source (Gavilan and Bernold, 1994). Supporting this view, Lingard *et al*. (1997) stressed that reducing waste at the source has the least detrimental impact on the environment, followed by reuse, recycling, composting, and incineration. Some researchers view reduction as the most effective and efficient waste management method since it reduces most of the waste disposal problems (Hao *et al*., 2007; Peng *et al*. 1997). Also reducing waste from its source saves money and landfill requirements (Tara 2011). In the Hong Kong context it was found that little consideration has been given to reducing construction waste at its source and that most of the time contractors adopt waste management plans onsite without integrating design and construction to minimise waste early in the design process (Jaillon *et al*., 2009).

There is a high potential in construction waste for reuse (Lingard *et al*., 1997). Wang *et al*. (2010) defined reuse as using the same material more than once in construction or use as a raw material for a new function. Lingard *et al*. (1997) understood reuse as the use of construction materials again without repossession. However, McDonough and Braungart (2009) pointed out that even though reusing waste may be seen as a really good thing for the environment in terms of waste reduction, some materials are not well designed for re-use and any toxins and contaminants they contain are simply being transferred to another place. Peng *et al*. (1997) stressed that recycling not only produces new materials out of waste but there should be an economic benefit. Reducing and recycling construction waste helps to reduce the usage of raw materials and has less impact on the environment (Craighill and Powell, 1997). Peng *et al*. (1997) highlighted ten factors for successful recycling: proper site selection, proper equipment, experience in recycling operations, trained supervisors and workers, knowledge about secondary material markets, financial capacity and knowledge of environmental and safety regulations. Better knowledge of equipment, waste separating techniques and quality controlling techniques will also help to improve the recycling of waste (Peng *et al*., 1997). Employees who are involved in the recycling of construction waste need to have proper training on the usage of recycling equipment, general operations of recycling, the values of different materials and how to work safely in a hazardous environment (Peng *et al*., 1997). According to Braungart *et al*. (2007), in many current process of recycling, materials lose their value as they circulate through industrial systems. McDonough and Braungart (2009) stressed that most of the time recycling is actually downcycling as recycling leads to diminishment in the quality of materials over time. McDonough and Braungart (2009) emphasised that downcycling can also increase contamination of the environment by realising toxins and dioxins during the process of recycling as most of the materials were not designed with recycling in mind. However, Hyder Consulting *et al*. (2011) cautioned that users of recycled materials need to be aware of differences between recycled materials and virgin materials. Furthermore, they noted that recycled materials may perform differently to virgin materials and sometimes perform better than virgin materials. Peng *et al*. (1997) argued that it is more cost beneficial to recycle and compost construction waste than to incinerate or landfill and the disposal of construction waste to landfill sites has a greater impact on the environment (Lingard *et al*., 1997). According to Hyder Consulting *et al*. (2011), resource recovery rates are higher in the regions where there is a strong market demand for recycled products with well-defined and well-exposed specifications to support recycled products.

The deficiency of legal land-filling sites, long transportation distances and high tipping fees, lack of enforcement measures and lack of knowledge of recycling options can encourage the illegal dumping of construction wastes (Katz and Baum 2011). Peng *et al*. (1997) identified that leachate, off-gassing, and potential groundwater contamination are typical problems associated with landfills. Peng *et al*. (1997) claim that incineration extracts energy from waste without producing toxic substances. Opposing this view, De Silva and Vithana (2008) stressed that incineration can be controversial due to the creation of toxic gas and ash, which can harm people and contaminate groundwater. McDonough and Braungart (2009) argued that even though incineration might be considered as preferable to landfilling as it produces energy out of waste, during the process of incineration dioxins and other types of toxins can be released as materials are not normally designed to be safely burned.

Compared to the construction stage, the design stage has been viewed as a stage which produces low waste (Australian Government, 2007). But most of the opportunities for waste generation can be minimised in the design stage by design for materials, standard sizes and flexibility, design for assembly and disassembly, design using prefabricated components, and design for ease of recycling (Australian Government 2007). On-site sorting of construction wastes is not yet popular due to lack of site space, skilled workers and necessary equipment (Hao *et al*., 2008). The most common approach of on-site sorting is sorting construction and demolition waste by hiring smaller bin hire operators to segregate waste manually, instead of using fixed equipment and automated sorting systems (Hyder Consulting *et al*., 2011). But with the trend towards increasing waste disposal charges, on site sorting should become popular (Hao *et al*. 2008). Effective implementation of waste management plans depends on the compatibility of these methods with the actual situation (Manowong, 2012). However, selection of the optimum method for waste management is difficult because wastes possess different physical and chemical characteristics depending on their origin. Furthermore, due to the presence of different waste management practices, natural and technical restrictions and conflicting objectives related to evaluation criteria for alternative management systems, this process becomes complicated (Kourmpanis *et al*., 2008). Therefore, this research aims to identify current construction waste management practices in South Australia in order to find ways to improve them. The next section describes the research method for this research.

3. RESEARCH METHOD

Interviews were conducted to gather data related to current waste management practices in South Australia. As described by Bennett (1991) interviews allow an in depth and in breadth examination of problems. Interviews can be unstructured and free-ranging, a general discussion, picking up points and issues as they emerge and pursuing them in some depth; or they can be structured around questions and issues determined in advance, based on theoretical principles, pre-conceived ideas or prior investigation (Bennett 1991, p.101). In this research semi-structured interviews were carried out and sixteen interviews were conducted with construction stakeholders including Architects, Clients, Construction Managers, Design Managers, Development and Technical Managers, Engineers, Facilities Managers, General Managers, Quality, Health, Safety, Environment Managers, Sustainable Advisors, Waste Contractors, and Waste Programme Coordinators. Initial contact with interviewees was made through the academic and industry networks of researchers who are involved in this research. Participants had a minimum of ten years' experience in the construction industry and at least five years' experience in waste management. Figure 2 presents the details of interviewees and interviewees were labelled using alphabetical letters from 'A' to 'P'.

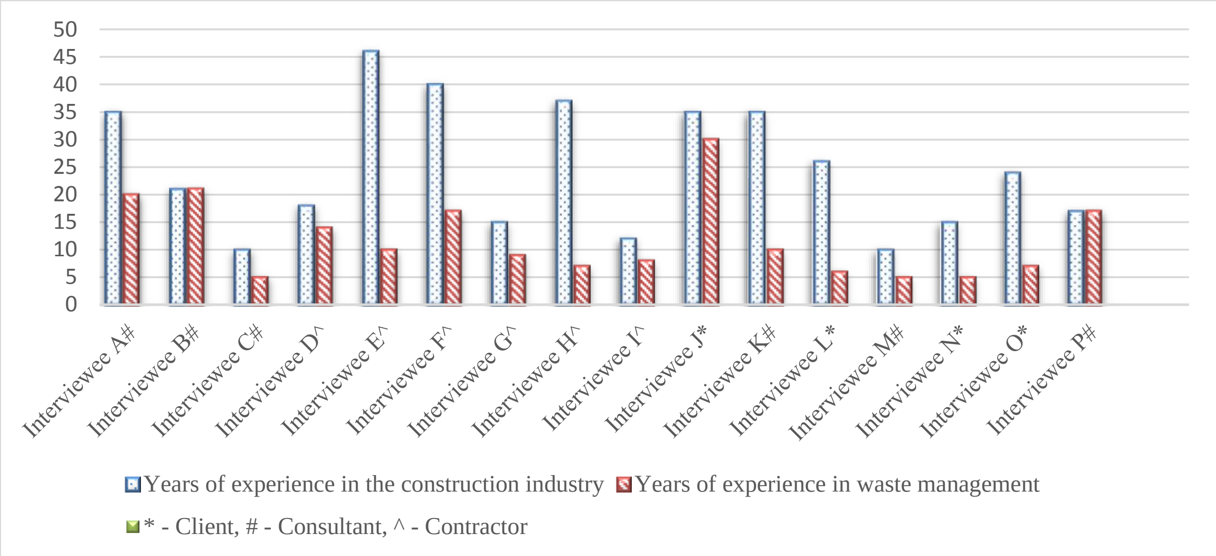

Figure 2: Details of Interviewees

As interviews were semi-structured, questions were varied according to the answers of respondents in order to get a holistic view on waste management practices. Interviews were tape recorded (with permission of the interviewee) to secure an accurate account of the conversations and avoid losing or misrepresenting data. After acquiring the free flowing texts from semi-structured interviews, data reduction and concept identification took place through code-based content analysis. Content analysis, a technique for gathering data, involves codifying qualitative information into pre-defined categories (codes) in order to derive patterns in the presentation and reporting of information (Guthrie *et al*., 2004). By using a qualitative content analysis programme (NVivo), the concepts arising from interview transcripts were coded. The data that was organised within the coding reports was mainly mapped using tables. The findings of this research are discussed in the next section.

4. RESEARCH FINDINGS

The following sub-sections describe findings of this research including different views of interviewees on waste management performance, current waste management practices, factors affecting waste management practices and factors which encourage the implementation of waste management practices in construction projects.

4.1. DIFFERENT VIEWS OF INTERVIEWEES ON PERFORMANCE OF CONSTRUCTION WASTE MANAGEMENT

Interviewees highlighted that there is no limit to the amount of waste that can be generated from construction projects because of the nature of construction projects. The following diagram shows different views of interviewees on construction waste management.

Construction waste is handled quite well (5)
Commercial projects perform well in waste management (2)
Government projects perform well in waste management (2)
Larger projects have better waste management practices (2)
The construction industry is going through a state of change in waste management (1)
Construction waste management is improving vastly (1)
Waste management practices are varied from organisation to organisation (1)

The construction industry manages waste really badly (1)
The residential sector is not performing well (2)
Although waste management has been improved over last 10 years, there is still a long way to go (1)

Figure 3: Different Views of Interviewees on Construction Waste Management Performance.
Key: Numbers at the end of each statement indicate the number of interviewees that agreed on that particular point.

As shown in Figure 3 interviewees had different views on the current level of performance of waste management in the South Australian construction industry. However, interviewees agreed that there is a fair amount of interest in waste reduction in the construction industry. In general it was perceived that commercial construction and public construction have better waste management practices than residential construction. Interviewee H stressed that especially in the commercial sector there is a tendency to reduce waste generation during construction delivery, manufacturing, ordering and even in post construction. He mentioned that in the past achieving an 85% recycling rate in construction projects was considered an unachievable target, but now some Green Star buildings end up with waste recycling rates of upwards of 90%. Interviewee B said that large projects employ sophisticated builders and tend to have better waste management practices than other projects. Interviewees stated that the industry is going through a transition and significant change in waste management has occurred in the last five years. Interviewee I also indicated that the overall performance of waste management in construction is improving vastly and now there are more facilities to cope with the waste streams. Interviewee H highlighted the influence of local governments, waste management operators, Zero Waste South Australia and waste management educators like KESAB Environmental Solutions, which promote waste management practices in the construction industry. Interviewee D pointed out that waste management practices vary from organisation to organisation and some organisations are better than others. However, according to Interviewee E, the construction industry is not good with waste management and still there is a long way to go, although it has been improved over the last 10 years. The following figure represents the different views of stakeholders on the implementation of waste management practices in construction projects.

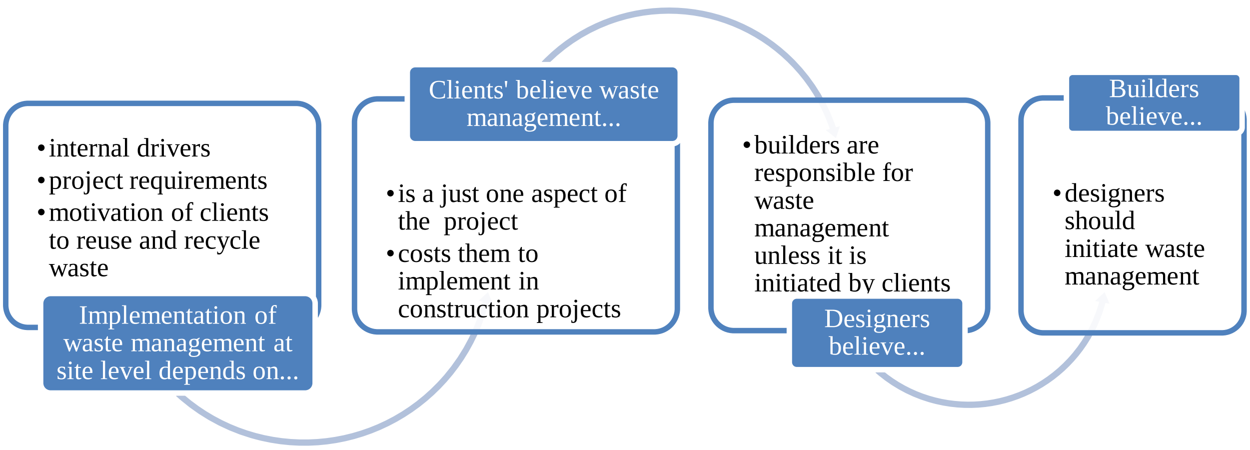

Figure 4: Different Views of Stakeholders about Implementation of Waste Management in Construction Projects

According to interviewees, most of the time drivers to implement waste management are internal. Interviewee I stressed that when it comes down to the individual site level, implementation of waste management practices totally depends on the project requirements and that decisions to reuse and recycle materials are solely based on clients' motivations and preferences. Interviewee L indicated that waste management is just one aspect of the overall management of the project and therefore, not a main consideration in construction projects. However, interviewees acknowledged that most of the time during the tendering stage, clients look at the contractor's overall waste management performance including what they are planning to do and what they have done in the past. Interviewee O pointed out that as there is a cost involvement in waste management, they have to decide whether it is worthwhile to make waste management a part of the contract or just leave it to the builder to manage construction waste. He highlighted that if there is no contract requirement in waste management, the amount of waste going to landfill is entirely up to the contractor and normally in higher value projects they have procedures to regulate waste management. Interviewee P also stated that in most construction projects, especially in commercial construction, contractors hire waste contractors to manage waste. However, the decision to implement waste management is driven by its financial returns. Interviewee A also mentioned that clients should initiate waste management in construction projects as it is very difficult to find time and money within their fee structures to act beyond the normal practice unless those changes are initiated by clients. Therefore, he stressed that in general, architects believe that builders are responsible for waste management and leave it with the builder. Interviewees G stated that initiation of waste management must come from designers. He pointed out that as builders they cannot change things as they are involved in the end of the process and they have to comply with the specifications. Accordingly, Interviewee P noted that in some specifications, consultants still highlight the need for virgin materials rather than recycled materials. He inferred that this is a barrier to the use of recycled materials. Therefore, it can be identified that all stakeholders have an important role in initiating waste management in construction projects and most of the time implementation of waste management depends on its cost and financial returns. The next sub-section describes current waste management practices in the South Australian construction industry.

4.2. CURRENT CONSTRUCTION WASTE MANAGEMENT PRACTICES AND FACTORS WHICH AFFECT CONSTRUCTION WASTE MANAGEMENT PRACTICES

Interviewees reported that most of the time, with the exception of office waste, all waste goes into a general waste bin to be sorted offsite by waste contractors. Normally at the end of each month waste contractors provide waste reports to the builders which allow builders to track different waste streams. However, as described by Interviewee D one of the main problems in waste management is separation of putrescible waste or organic waste from other waste as workers tend to put all waste in one bin. At the same time some waste contractors do not want waste to be separated onsite as they make money out of waste separation. For example Interviewee E mentioned that:

> "Very early in the phase when people start talking about waste minimisation; we did have an issue with one company where the people who collected the waste did not want the waste separated. We setup the site where… steel elements in one bin, plasterboards in another, concrete in another and a general waste bin for everything else. We couldn't find anybody to collect them separately… the waste collection people made their money out of separation. So they do not want us do on the sites. I think that attitudes changed a bit."

Interviewee P also pointed out that when waste is mixed, it increases the waste disposal rate per tonne. As such, it is really important to separate waste wherever you can. However, in congested sites there may not be enough space for onsite waste separation. In such cases, there may be only one bin and waste will be sorted off site. Figure 5 summarises general methods of waste separation in construction projects.

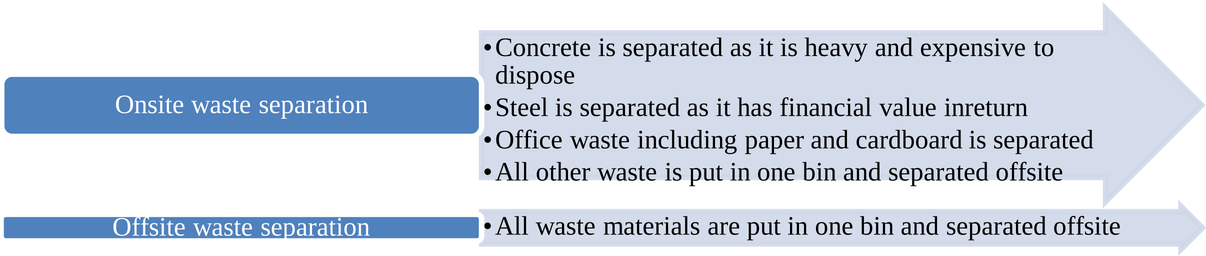

Figure 5: General Methods of Waste Separation in Construction Projects

Interviewee G also emphasised that site space is a key limiting factor in waste management and sometimes it is not practical to have separate bins for different waste streams. However, Interviewee I mentioned that waste can be better recovered when there is an onsite waste separation system. Therefore, the biggest challenges are to find enough space for onsite waste separation and to educate workers to use multiple bins. However, he said that when it comes to waste management the primary motivations of the industry are financial and a lot of work still needs to be done to change mind-sets as its comes down to dollars and cents. Accurate estimation of material requirements also plays an important role in waste management. However, Interviewee E asserted that there is a tendency to over order materials in construction projects and throwaway both excess materials and off cuts. Interviewee D said that to avoid this problem their company has contractual instruments and procedures for insuring accurate estimation of material requirements, which helps to minimise the amount of waste generation. For example, he noted

> “One general principal we have on the project is we don’t allow the concreter to wash the concrete trucks on site. That’s a good driver because it means that the concreter needs to measure required concrete quantity very carefully, because if he orders too much he needs to take it away again.”

Interviewee D pointed out that in their projects they follow the waste management hierarchy and they have site oriented waste management plans. Also he mentioned that the waste management objectives and protocols are highlighted during weekly toolbox meetings and in subcontractor start up meetings to encourage workers to manage construction waste. However, company policies relating to waste management in construction projects vary according to project costs. For example, Interviewee O also stated that for higher value projects (projects costing more than $4million) they make waste management part of the contract and they do have procedures to regulate waste management practices. But for small projects which cost less than $4million, they only highlight the importance of waste management during the project meetings and the amount of waste going to landfill is entirely up to the contractor. Interviewee G stressed that as a Tier 2 builder they have an environmental management plan, which includes details about waste collection, recycling and minimisation of landfilling. He noted that as head contractors they control onsite waste management such as waste collection, separation and coordination, and disposal in coordination with the waste contractor. He said that they have a system to monitor waste generation and they receive a report at the end of each month for every single site, including how much waste is collected and recycled in each and every waste category. He claimed that his company achieve over an 85% recycling rate across their sites.

Interviewee H mentioned that there are problematic materials, including products like gypsum or plasterboard and asbestos that that do not have recycling options and can only be disposed of according to regulations. Interviewee E pointed out that excavated material is also a big issue in construction projects. He asserted that excavators have a tendency to tender based on the assumption that they can deliver excavated materials to somewhere else. Therefore, he revealed that most of the time the costs associated with excavation are not excavation costs per se, but transportation and dumping costs. He highlighted the importance of preplanning excavation activities during the design stage to minimise undue waste generation. Interviewee C stressed that for a long time, waste management was not considered a design exercise and it was left out from the design process. Interviewee I stated that as waste contractors their company supplies waste receptacles and the transportation facilities from sites to recycling facilities and provide consultancy services to select the best waste management practices for different projects. They also provide waste reports to construction sites and to the companies. He said that a "lot of construction businesses now want their waste to be recycled or reused… we can offer the wide range of services. But it depends on what customer the wants." Interviewee O said that in their projects, contractors have to submit waste reports at the end of each month and then try to minimise the amount of waste that goes to landfill. However, he acknowledged that currently they do not systematically analyse this data and only use it to get some idea about their waste management performance.

Interviewee D highlighted problems with subcontractors in the waste management process. He pointed out that as a Tier 1 contractor they have to deal with a large number of subcontractors. He said that:

> "When we asked the subcontractors to also do the same, to provide us with their environmental management policies, more often they… are very generic. So it's done once and it's sat in folder somewhere no one looks at it. So when they come and work for us we say we want to see that information and then we ask them to make it specific to the project."

Packaging is also considered as a massive problem in waste management. However, from the interviews it can be identified that normally builders pass on their responsibility to subcontractors and subcontractors pass their responsibility to suppliers or manufacturers. For example Interviewee D further mentioned that they try to minimise the amount of packaging that comes to sites in the first place. He said that sometimes it is not possible when they have items like delicates which need padding for support. But in many other cases it is possible to have all the packaging removed from the items before they come to the site. Normally when the contractor collects materials from suppliers, contractors advise suppliers to remove the packaging, dispose it and then bring materials to site. However, Interviewee D said that "it doesn't always work but for large, bulky items it's been a very good practice." According to interviewees, the following are the most common types of materials that are reused and recycled in construction projects.

- Reinforcement and other metals
- Concrete
- Bricks and other masonry products
- Rubble
- Plastics
- Timber
- Decorative materials such as carpets and floor boards
- Paper
- Cardboard

As stressed by Interviewee I, in general, steel is the material with the highest recycling rates in construction projects. He further added that:

> "… we have different industries we take concrete, bitumen and make new products… For plastics, cardboard, steel… get recycled and back into the commodity exchange… timbers and those sort of thing depending on what type of timber it is… and how it gets recycled."

Interviewee I mentioned that there are always products that cannot be recycled because of their product qualities. Interviewee D observed that there has been an improvement in technology for reused and recycled materials in construction projects. For example, he remarked that all reinforcement in Australia is made out of recycled steel. Other products that they extensively recycle are hard materials like rubble for the construction of roads. Interviewee B also stressed that metals are often recycled and there is a major industry for recycled metal. Supporting these views Interviewee E said that "20 years ago everything got scrapped. But now everything has been improved and reusing aggregate out of concrete is a pretty common thing. Also reusing steel controls the import of virgin materials as well." Interviewee A stated that one thing that is around at the moment is recycled plastic which is used for decking. Interviewee H claimed that the market is only prepared to go for recycled products when price is low and the quality is good. Furthermore, Interviewee F asserted the difficulty to use recycled materials effectively due to some quality issues. For example he noted that "even though we use crushed concrete, most of the time we have to use fresh aggregate. We can only put very little amount of crushed concrete and high percentage needs to come from virgin materials." Therefore, it can be argued that even though the reuse and recycling of materials has been improved over the past decade, there are still some problems associated with their quality. Figure 6 represents the different factors that affect recycling of construction waste.

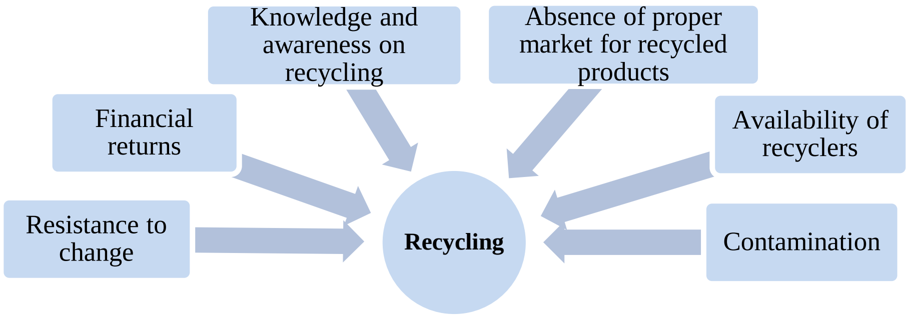

Figure 6: Factors Affecting Recycling of Construction Waste

As shown in Figure 6, different factors affect decisions related to recycling and the use of recycle materials in construction projects. Interviewee A noted that even though recycling is being embraced in the construction industry, there is always a level of resistance to change. At the same time he pointed out that as people always compare available options, in order to change consumer behaviours, it is necessary to show them that there is a cost and time saving by using recycled products. He further added that "unfortunately we are driven by our hip pocket… It is being like voting in elections. People take notice when it affects their pockets." Agreeing with this view Interviewee N stressed that as cost is one of the main considerations in construction projects, only materials that have financial returns get recycled in construction projects. He further added that:

> "I don't know whether contractors have a global view on recycling or whether it means better financial return for them… things such as steel or any metal product natural rock product, they tend to all get recycled."

He affirmed that designers are keen to recycle and the availability of recycling facilities also impacts on waste management as the easier it is for contractors to send their materials to recyclers, the more likely they will be to do so. Furthermore, Interviewee N confessed that even he does not know what all the products that can be recycled are and he is not sure whether all contractors know about them. Therefore, he recommended that efforts should be made by the relevant authorities to raise awareness of recycling in the construction industry. Interviewee O also highlighted that the ability to recycle also depends on the availability of recyclers. He mentioned that most of the time people do not know what is recyclable and what is not and whether there are enough facilities to recycle. However, Interviewee F criticised current waste management practices and pointed out the absence of proper markets for other recycled products. He further added that there is no proper manufacturing industry in Australia and most of the materials have to be imported from overseas. He questioned the possibility of recycling materials such as aluminium, glass and carpet as most of those materials are imported from overseas. He further added that most of the time recycling is expensive and not cost effective to implement. He highlighted the necessity of secondary markets for recycled products. He emphasised that recyclers need to demonstrate that their products are also as strong and of the same quality as virgin materials. Interviewee M indicated that even though there is a market for certain recycled products, most of the time people do not have confidence to use them because of issues like contamination. Agreeing with this, Interviewee C affirmed that when using recycled materials, it is necessary to check available standards in terms of provisions relating to the use of recycled materials. He stated that sometimes consultants do not want to specify recycled materials in construction projects as there can be impurities in those materials. He noted that most of the time even recyclers cannot guarantee the quality of their products and therefore, there are limitations in the use of recycled materials. The next sub-section discusses factors which encourage the implementation of waste management practices in construction projects.

4.3. *FACTORS WHICH ENCOURAGE THE IMPLEMENTATION OF WASTE MANAGEMENT PRACTICES IN CONSTRUCTION PROJECTS*

The following figure represents the factors which encourage implementation of waste management practices in construction projects.

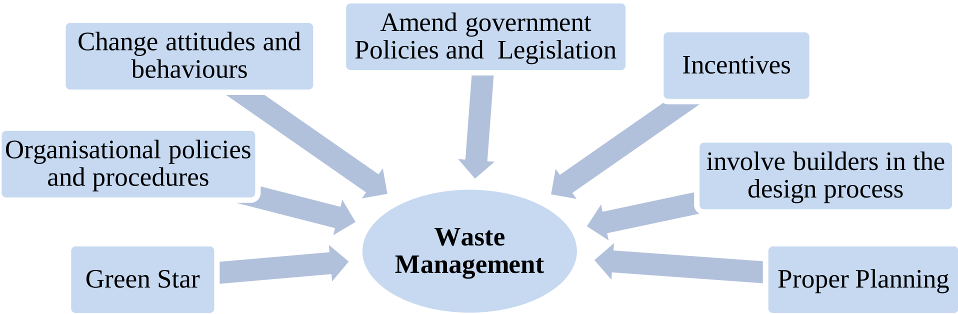

Figure 7: Factors which Encourage Implementation of Construction Waste Management

According to the interviewees, the Green Star rating system encourages the implementation of waste management in buildings. Interviewee O further stressed that in order to get higher ratings in Green Star, it is necessary to recycle and use recycled materials as much as possible in Green Star buildings. Interviewee C also pointed out that it is important to have standardised practices and incentives programmes such as Green Star which encourage recycling and the minimisation of waste generation. At the same time in some client organisations there are company policies and guidelines for ecologically sustainable development (ESD) planning and design delivery. Interviewee O added that "we do have lot of … statements within our policies and frameworks to encourage contractor and designer to deliver us with a minimal… landfill." Interviewee L said that when working on government projects government clients are very keen on meeting existing legislation and policy standards and they highlight these requirements in their tender documents. Interviewee K pointed out that waste management is an important part of project planning. He also noted that as the construction industry consumes a massive amount of resources, by minimising waste generation it is possible to reduce resource consumption in construction projects. Interviewee P revealed that it is necessary to change attitudes towards waste. He added that "it's not, we should call it waste, it is a resource… there are companies now that don't look from that material as being waste but as a resource… that's changing mind-set." Interviewee C also indicated the importance of changing mind sets of people around the use of recycled materials. He asserted that it is necessary to amend some of the Australian standards which might restrict the use of some recycled materials. Interviewee G highlighted that motivation to recycle is driven by incentives. He mentioned that there should be clear guidance, incentives and authorities to boost and encourage the usage of recycled products in the construction industry. Interviewee H noted that:

> "What we've got at the moment is the… legislated price but… if we go to the market trading type principle where there is incentive and there are certainly advantages for recycling or diversion to resource taxation wise or… just through whatever goes to landfill… some sort of mechanisms that encourages the developers and builders to make some money. So if you can show the developer… opportunities to make money or save money then that is the carrot approach that should be encouraged?"

Interviewee E also asserted the importance of reusing materials by modifying them instead of using new materials and of involving builders in the design process to minimise waste generation. Interviewee K stressed that waste is easily generated in the construction industry and it is necessary to use good planning to minimise waste generation. Interviewee D indicated the importance of having a good framework for waste management in construction projects. The conclusions drawn from this study are discussed next.

5. CONCLUSIONS

Interviewees highlighted that there is no limit to the amount of waste that can be generated from construction projects because of the nature of construction projects and that most of the time drivers to implement waste management are internal. Interviewees stressed that the construction industry is going through a transition with regards to waste management and that waste management practices vary from organisation to organisation. Site space was raised as the main limiting factor in the implementation of onsite waste management practices. Interviewees highlighted that generally it is believed that builders are responsible for waste management unless it is initiated by clients. Key factors which affect recycling in construction projects are resistance to change, financial returns, availability of recyclers, knowledge and awareness on recycling, contamination and absence of proper markets for recycled products. However, interviewees indicated that even though there are programmes like Green Star which encourage recycling and waste minimisation; waste management was not well integrated into the design process and has not been for a long time. The findings of this study have a number of important implications to improve waste management practices such as improvements in rating systems like Green Star, organisational policies and procedures, changing attitudes and behaviours, amending government policies and legislation, improving financial incentives and introducing ecological costing, involving builders in the design process, and practicing proper waste management planning on construction projects. As would be expected in a highly competitive and profit-driven industry, issues associated with costs and financial management were highlighted as key in determining waste management practices. As such, the study also points to the importance of addressing systemic issues of political economy, including the externalisation of environmental and ecological costs and the pursuit of endless growth on a planet with finite boundaries and resources.

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KEY CHALLENGES IN CONDUCTING DEVELOPMENT APPRAISALS IN SRI LANKA

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ABSTRACT

Property development is an activity constituent with both huge returns and risks. Development appraisal is a method, primarily used to check the financial viability of a property development project. In Sri Lanka, it is known as feasibility study. Several development appraisal techniques are practised in association with risk analysis methods in the Sri Lankan property market. Development appraisal is subjected to many variables and therefore it is a challenging task. This research investigates the challenges in conducting development appraisal and suggests ways of resolving such challenges.

Survey approach with 32 sample questionnaires was adopted in investigating the research problem. The Relative Important Index was used to rank the challenges based on the magnitude and significance of challenges. The research found that discounted cash flow method is being used extensively in Sri Lanka. Top ranked key challenges are client's influence and estimating the variables. The research suggested carrying out detailed market survey to obtain relevant data, maintaining internal building cost database and practicing risk analysis techniques to overcome the challenges. Therefore, the research recommends that a Quantity Surveyor who involves in development appraisal could provide building/construction cost data, calculate the net lettable areas of the building, and determine the timing of cash inflows and outflows during construction period.

Keywords: *Appraisal; Challenge; Development; Feasibility Study; Sri Lanka.*

1. INTRODUCTION

Property development is defined as "a process that involves changing or intensifying the use of land to produce buildings for occupation" (Wilkinson and Reed, 2008: 2). Development appraisal is an important task undertaken during the initial stages of the property development process (Wilkinson and Reed, 2008). Development appraisal was termed as the calculations, which can inform the property developer on the cost to pay for the land in its existing state or what profit the property developer is to make from the proposed development (Bello and Babajide, 2005). Morley (2002) stated that development appraisal is approached in a particular manner by each of the developers in the property market, primarily because of their differing development objectives.

Conducting a development appraisal is a challenging task. Morley (2002) highlighted that the development appraisal concept and method is straightforward, but the estimation of the many variables contained in the appraisal is difficult. Further Morley (2002) expressed that the final residual answer is subjected to a high degree of sensitivity to minor changes of some variables. Complications that distort the accuracy of development appraisals are the imperfection of the property market, the lack of central register of sales, the individual characteristics of buildings and confidentiality of information (Babawale and Omirin, 2012). Isaac *et al*. (2010) pointed out that forecasting would be difficult since there are practical difficulties in obtaining reliable local or project specific time series data to use in the forecasting process.

According to Babawale and Omirin (2012), valuers are often dissatisfied on reliable transactional and other relevant data inadequate in emerging markets because, the publication of such data is not yet an established norm. The property market in developing countries is driven underground by high transaction taxes, levies and by rent controls (as cited in Babawale and Omirin, 2012). Further, Babawale and Omirin (2012) expressed that the basic information on cost, rental and capital values and yields

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required for accurate valuation are not available in the right quality and quantity. Sri Lanka is a developing country (International Monetary Fund, 2012) and an emerging market (BBVA Research, 2012). Therefore, the above characteristics would fairly pose challenges when conducting development appraisals.

Development appraisal requires inputs from different parties including the developers, Quantity Surveyors and agents (Wilkinson and Reed, 2008). The main contribution of a QS is providing building cost details (Morley, 2002). Development appraisal is an important activity which will display beforehand the financial viability of a given proposal. Thal (1982) stated that virtually every real estate disaster is preceded by at least one feasibility analysis that assured its success. According to Bello and Babajide (2005: 1103), “In recent times, a significant number of development projects that were judged viable by development surveyors in their development appraisals have turned out to be unviable”. Proper knowledge on the challenges would aid in the preparation of more meaningful appraisals that could benefit the client and other parties concerned. Thus, there are challenges remain widespread within the practice of development appraisals.

1.1. AIM AND OBJECTIVES

The aim of this research is to identify and analyse the key challenges in conducting a development appraisal in Sri Lanka. The following objectives are set out to achieve the aim of this research,

1. Identify the different techniques used for conducting development appraisals in Sri Lanka
2. Identify possible challenges in conducting a development appraisal in Sri Lanka
3. Determine the key challenges then analyse and discuss them
4. Identify the roles of QSs’ in conducting development appraisals in Sri Lanka
5. Propose solutions to the key challenges identified, in general and specifically from the view point of a QS.

2. LITERATURE REVIEW

2.1. INTRODUCTION OF DEVELOPMENT APPRAISALS

There is no exact and specific definition for development appraisal available. Grimley (2009) stated that there is no set professional code of conduct for development appraisal and the assessment of development viability. It is also known from various titles whereas according to French and Gabrielli (2006) development appraisal is the title given in the United States of America, in the UK it is known as residual valuation and in Europe as a feasibility study. Pagourtzi, Assimakopoulos, Hatzichristos and French (2003) identified development appraisal as one of the traditional real estate valuation methods. It can be explained as a method of valuation used on property with development potential.

There are two basic objectives of development appraisals (Bello and Babajide, 2005; Byrne, McAllister and Wyatt, 2011; Newell, 1989; Ratcliffe, 1983a). First is providing a framework from which a developer can obtain a measure of the likely profit to be obtained from undertaking a development scheme and second is to assist the developer in identifying the maximum price that can be paid for a site for a given development proposal in order to achieve a fixed expected profit.

Development appraisals can take many different forms and there are various guidebooks and best practice on techniques (Grimley, 2009). Ratcliffe (1983a) contended that there have been a number of attempts to standardise the procedure of residual valuation and an example is the ‘Property Development Feasibility Tables’ produced by Bernard Williams and Associates. Until relatively recently, the discipline of development appraisal has remained the provenance of surveyors and developers (Byrne *et al*., 2011). Further, Byrne *et al*. (2011) stated that it has largely been ignored by other participants in the development process, particularly planners, architects and construction specialists. Most major firms of surveyors will prepare development appraisals according to their own in-house formats (Ratcliffe, 1983a). The use of computers and software packages for development appraisal have become commonplace (Morley, 2002). Some developers have their own tailor made in-house software or programs to conduct development appraisals and others use off-the-shelf software packages; where two most popular such off-the-shelf packages are Circle Developer and Pro-Dev (Grimley, 2009).

2.2. CHALLENGES IN CONDUCTING DEVELOPMENT APPRAISALS

Obtaining Input Data from Sources

Obtaining many variable input data such as rent and sales values, investment yields, building cost data, professional fees, interest rates etc. from various sources is a challenging task (Isaac *et al*., 2010; Ratcliffe, 1983a; Wilkinson and Reed, 2008).

Estimating and Adjusting the Data Obtained

There are several assumptions that the appraiser would make in carrying out a development appraisal. Byrne *et al*. (2011) expressed that there is substantial uncertainty in the key assumptions of costs and revenues. Further, Ratcliffe (1983b) concluded that in practice, the various elements in a scheme are adjusted and aligned to take account of physical and economic factors prevailing in the market for a particular site at a given time. The data obtained might need to be refined by the process of estimation/forecasting in order to suit the given appraisal at hand.

Client Pressure and Influence

From the appraiser's perspective the pressure and influence from the client would pose challenges when conducting a development appraisal. Levy and Schuck (1999) remarked that clients are frequently motivated to influence the outcome of a valuation intentionally or unintentionally, implicitly or explicitly. These would be either in the form of tampering of outcomes to convince funders, partners and government for negotiation purposes (Babawale and Omirin, 2012), sophisticated requirements (Ogunba and Ajayi, 2007), time restriction given for completion, limited resources provided, or by threats and reward tactics (Smolen and Hambleton, 1997).

Skills and Competencies Required

A development appraisal demands a specific set of skills and competencies from the appraiser. A lack of such would also pose challenges. Some essential skills include the identifying and obtaining the inputs from the variety of sources and different parties (Wilkinson and Reed, 2008), in-depth knowledge of the property market (Brandon, 1992; Adegoke, 2008) including comprehensive knowledge of the transaction prices, rent levels and average cost of construction work (Skarzyński, 2006), estimating skills (Lovell, 1994) and presentation and communication skills (Newell, 1989).

2.3. REASONS FOR THE CHALLENGES

A major reason for the challenges in obtaining data is the limitations of price information due to the imperfect nature of the property and construction markets. Property development is highly sensitive to the effects of economic climate and government action (Ramachandra and Zainudeen, 2006). KPMG (2012b) stated that there is a tremendous variation of per perch land registered prices in Colombo city which was due to socio-economic, legal, regulatory issues and pressure of the state. Harvard (2008) stressed that property markets can be hard to anticipate as the demand is continually changing; therefore developers must be careful if they are analysing past trends to determine future demand. The rapid changes and volatility is evidenced when observing the building tender price inflation in Sri Lanka, for example in 2005 it was 32.4% whereas it dropped to 2.1% in 2010 (Gardiner and Theobald, 2011).

Ofori (1990) described that pre-design market surveys and feasibility studies are difficult due to the non-existence of central data banks in the construction industry. The Research Intelligent Unit remarked that gaining access to registered property prices in Sri Lanka is a difficult task (KPMG, 2012a). The Investment Property Databank (IDP) provides indices and market information on the real estate industry across 32 countries (IDP, 2013). However Sri Lanka is not listed in that database. Perera (1996) stressed on the need for an improved land information system in Sri Lanka. Confidentiality and lack of transparency of property price information is a global problem; in developed countries such as the UK (University of Reading, 2010), in mature markets such as Taiwan (Lin and Chang, 2012) and also in developing countries (Babawale and Omirin, 2012).

The complexity of the property highly affects the valuation. Each property is heterogeneous because of its exclusiveness of its location. This increases the challenge when adjusting comparable data.

McAllister and Loizou (2009) found that heterogeneity of the property with varied specifications would make the input variables of the appraisal prone to increased uncertainty.

Babawale and Omirin (2012) remarked that clients' pressure on the valuers to report their desired results would increase as a result of the increase of the criticality of the valuation to the clients' interest. Ogunba and Ajayi (2007) contended that sophistication of client requirements was due to rapid changes in the property market such as swift rent reviews, surge of institutional investors, advent of new property finance methods and use of investment portfolios. Lin and Chang (2012) stated that the lack of transparent market information was a reason for high client influence.

According to Baum and Crosby (1988), valuers' skills, experience and judgement affect valuation accuracy. Gallimore and Wolverton (2000) also stated that additional criteria such as ability of valuers in applying valuation models, processing and interpreting information under different conditions affect valuation accuracy. Levy and Schuck (1999) found that valuers used cognitive shortcuts (heuristics) to value property which are less accurate.

2.4. SOLUTIONS FOR THE CHALLENGES

Many of the reasons for the challenges as highlighted before are external to the appraiser, however amidst this the appraiser still can take measures to counter the challenges. Marshall and Kennedy (1993) concluded that practitioners must acquire a greater knowledge of the factors involved in the development and investment process. This is necessary especially for the key inputs which the output is highly sensitive to (Byrne *et al*., 2011).

Risks related to the accuracy of input variables are inevitable and therefore techniques to incorporate risks should be used in development appraisals. Newell (1989) suggested methods to incorporate risks in development appraisals such as including a higher profit level, contingency allowance, sensitivity analysis, scenario planning and testing for the impact on expected profit of trading risk off against profit. Other methods as stated by Babajide (2006) which were used in Lagos, Nigeria include risk adjusted discount rate, certainty equivalent method and Monte Carlo simulation. Baroni, Barthélémy and Mokrane (2007) found that the use of simulated cash flows by using the Monte Carlo simulation enables the user to estimate the real estate portfolio's price distribution for any time horizon and enables values-at-risk computations.

The use of computer packages is helpful when using advanced techniques. French and Gabrielli (2006) studied the use of a computer programme called 'Crystal Ball' that allows the appraiser to model this uncertainty by carrying out multiple calculations and they argued a one-dimensional simulation is better than single-point estimates such as cash flow techniques since it displays the true probability of risk.

Lovell (1994) concluded that the appraiser must strive to be objective amidst pressure and not to influence his professional judgement with personal beliefs and socially desirable objectives. Further, Lovell (1994) stressed that to minimise forecasting errors valuation methods must be selected carefully, not because they are simple; to examine assumptions carefully, not to over rely on historical data and the use of a rigorous systematic approach. Maroney (2005) suggested that relevant experience of an appraiser, proper development of a transparent and a detail report is required to optimise good service to the client.

2.5. QS'S INVOLVEMENT IN DEVELOPMENT APPRAISALS

The main contribution of a QS as identified by several researchers is providing building cost details (Morley, 2002; Wilkinson and Reed, 2008). Ashworth and Hogg (2002) reviewed the development of quantity surveying and identified that currently many quantity surveying firms have extended the range of services offered to clients, had a shift from cost to value and this included the provision of development appraisals. The QS has an edge over other professionals for the above skills given due to the QS's proficiency and background. Brandon (1992) stated that QS has an in-depth knowledge of the property market and also is highly proficient in estimating.

3. RESEARCH METHODOLOGY

3.1. RESEARCH STRATEGY AND APPROACH

The research strategy adopted for this study is a quantitative research strategy. Bryman stated the role of the quantitative research as fact-finding based on evidence or records (as cited in Naoum, 1998). The literature review brought to light answers for objectives 2, 4, and 5 of this research. This justifies the availability of related evidence and records. Bryman further stated that in a quantitative research the relationship between theory and research are tested or confirmed.

Survey that is conducted to advance scientific knowledge, referred as survey research approach (Kraemer, 2002) was adopted to the current research. According to Naoum (1998), surveys are used to gather data from a relatively large number of respondents within a limited time frame. Therefore, a survey would make it possible to obtain a broader general view of the context prevailing in Sri Lanka rather than an in-depth analysis, which ultimately is needed to fulfil objectives 1, 2, 3 and 5 of this research. From a survey very large samples are feasible and thus it makes the results statistically significant even when analysing multiple variables. This research consisted many variables falling under the areas of the techniques, challenges, solutions and the roles of the QS that were required to be analysed.

3.2. DATA COLLECTION TECHNIQUE

The method used to collect data for this research was through questionnaires. According to Naoum (1998) the main advantages of using questionnaires include economy, speed and consultation. A questionnaire would be suitable in situations where the purpose can be met with questions that are not over-elaborated. All of the objectives of this research can be given as questions for the respondents to select or rate as appropriate. Considering the numerous advantages as well as the suitability of questionnaires for the context of this research it was adopted as the data collection technique.

3.3. SURVEY DESIGN

Sample Design

A sample was termed by Naoum (1998) as a specimen or a part of a whole population which is drawn to show what the rest is like. Levine *et al*. (2008) stated that rather than selecting every item in the population, statistical sampling procedures concentrate on a small representative group of the larger population to collect data. This research used a convenience sampling technique. In such a sampling technique the items selected are easy, inexpensive, or convenient to sample, without knowing their probabilities of selection (Levine *et al*., 2008). Since development appraisals are done in several types of organisations and different professionals get involved in it, the sampling profile included respondents from these organisations consisting construction consultancy firms, management and financial consultancy firms and property development firms. Taylor (2010) contended that if a survey sample size is more than 30 it would reflect the characteristics in the population. Thus, a total number of 48 questionnaires were distributed and 32 were received.

Questionnaire Design

The questionnaire contained five sections which were structured around the aim and objectives of the research. The first section contained general information such as the respondent's name, designation, employed organisation and experience. With the name of the organisation and designation it was possible to get an idea on what type of companies that does development appraisals as well as the type of professionals involved. Section two of the questionnaire was based on objective 1 which contained details of the techniques used to conduct development appraisals and the risk analysis techniques. Section three of the questionnaire was based on objective 2 which were the challenges in conducting development appraisals. It included opinion questions on a 5 point Likert-type response scale. Response scales enabled to measure the different attitudes towards a statement and this was used for subjective measurements. For each challenge the respondent was required to rate two perspectives of a challenge.

The first was the magnitude of the challenge which is the size or extent of the challenge and the second was the significance of that challenge to the development appraisal process and outcome.

Section four included a list of possible solutions to mitigate the challenges which was based on objective 5 of the research. The respondent had to rate the importance of each solution for its ability to resolve or reduce the challenges based on a 5 point Likert-type response scale. Section 5 of the questionnaire was based on objective 4 which were to identify the roles of QS when carrying out development appraisals. Here the respondents were required to rate from a 6 point Likert-type response scale on the frequency of each role being done by a QS. An electronic format of the questionnaire was also prepared using the software Adobe Acrobat X Pro and was distributed via email.

3.4. DATA ANALYSIS TECHNIQUES

The data collection techniques that are useful in analysing quantitative data are statistical techniques. The scale of measurement was selected first which enabled to select several statistical techniques.

Scale of Measurement

As stated by Ary, Jacobs and Sorenson, there are four categories of measurement as given in the Steven's Scale of Measurement; which includes nominal, ordinal, interval and ratio scales (as cited in H.N. Boone and Boone, 2012). The ordinal scale is a ranking or rating scale which can be used when attitudinal questions are asked and the respondents required to rate the magnitude (Noaum, 1998). In this scale the interval between the ratings are not equal and it only implies a greater than relationship and does not indicate how much greater (H.N. Boone and Boone, 2012). The scale that is appropriate for this research and thus was selected was the ordinal scale since the questions asked were attitudinal questions and the ratings namely: high, medium and low, only indicate a greater than relationship and not indicate how much greater.

RII

To determine the relative ranking of the factors, the results obtained from questionnaire survey were transformed to importance indices based on the following formula (Kometa *et al*., 1994).

$$RII = [\sum (W \times n) \times 100] / A \times N \quad \text{(Eq.01)}$$

where, W = constant expressing the weighting given to each response, A = the highest weighting, n = the frequency of responses of that weight and N = total number in the responses.

In this research the RII was used for the ranking of the frequency of usage of techniques for conducting development appraisals in Sri Lanka, the frequency of usage of risk analysis techniques, the magnitude and the significance of challenges in conducting development appraisals, importance of solutions to deal with the challenges and the frequency of the roles carried out by a QS when conducting a development appraisal.

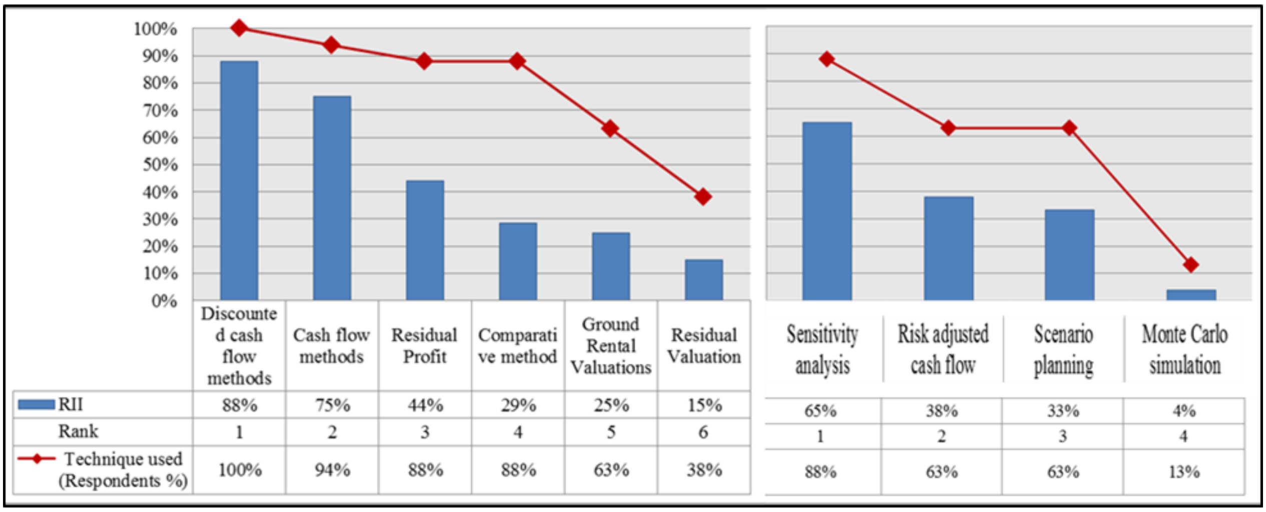
Frequency Distribution Methods

Frequency distribution methods would distribute the data into categories or classes and display the frequency belonging to each category by percentages or by actual numbers (Naoum, 1998). This research used frequency distribution methods of bar charts to analyse the use of techniques to conduct development appraisals and risk analysis techniques to incorporate risks into development appraisals.

4. DATA ANALYSIS AND DISCUSSION

4.1. TECHNIQUES USED TO CONDUCT DEVELOPMENT APPRAISALS AND TECHNIQUES USED TO INCORPORATE RISKS IN SRI LANKA

To identify the frequency of usage (i.e. the regularity of use) of each technique a 4 point Likert-type scale which represents 'high', 'medium' and 'low' frequency of use were assigned values of 3, 2, 1 and another point to represent the technique not being used was assigned a value of 0. Thereafter the RII was calculated and the techniques ranked. A higher RII value represents a higher rank and vice versa. Furthermore with the number of respondents who did not use the technique known it was possible to calculate how many respondents had used a given technique at least even once.



	Discounted cash flow methods	Cash flow methods	Residual Profit	Comparative method	Ground Rental Valuations	Residual Valuation
RII	88%	75%	44%	29%	25%	15%
Rank	1	2	3	4	5	6
Technique used (Respondents %)	100%	94%	88%	88%	63%	38%

	Sensitivity analysis	Risk adjusted cash flow	Scenario planning	Monte Carlo simulation
RII	65%	38%	33%	4%
Rank	1	2	3	4
Technique used (Respondents %)	88%	63%	63%	13%

Figure 1: Techniques Used to Conduct Development Appraisals and Incorporate Risks

Cash flow techniques take prominence for conducting development appraisals where all respondent had used the discounted cash flow methods and 94% having used cash flow methods (non-discounted). With a RII of 88% the discounted cash flow methods also have the highest usage among the respondents.

The residual valuation technique has the lowest usage among the respondents with a minute RII value of 15%. It was also found that only 38% of the respondent had used this technique even once to conduct development appraisals. The literature review highlighted that this technique was criticised in the UK due to the inherent weaknesses and limitations and these can be reasons for its unpopularity in Sri Lanka as well.

It was found that all of the respondents had used even one risk analysis technique at least once when conducting development appraisals but there was no high frequency of usage of the techniques. According to Babajide (2006), in Lagos and Nigeria the use of sensitivity analysis, risk adjusted cash flow approach and Monte Carlo techniques for development appraisals were 45%, 0% and 0% respectively. When compared with the obtained results the use of each of the above techniques in Sri Lanka corresponds to 88%, 63% and 13% respectively. This shows that in the Sri Lankan context more prominence is given to incorporate risks into development appraisals as compared to that of Lagos, Nigeria.

4.2. Identification of Key Challenges in Conducting Development Appraisals in Sri Lanka

For each challenge there were two 5 point Likert-type response scales, one for the magnitude of the challenge and the other for the significance of the challenge (Refer Section 3.3.). The 5 ratings were 'very low', 'low', 'medium', 'high' or 'very high' which were assigned values of 1, 2, 3, 4 and 5 respectively and then the RII values calculated. Two conditions were followed to determine a key challenge, which are:

Firstly the RII based on the significance of the challenge had to be over 70%. The rationale here is that a very large (high magnitude) challenge if it does not impact the outcome/process of the development appraisal calculation substantially then the effect from that challenge towards the overall development appraisal would be low. Therefore, it is not meaningful to further consider, discuss or study. Secondly the RII based on the magnitude of the challenge had to be over 50%. If both conditions were met it was considered as a key challenge. If the rank given by based on the magnitude was the same for two or more issues they were ranked considering the highest RII values of the significance of challenge.

Table 1: Key Challenges in Conducting a Development Appraisal in Sri Lanka

Key Challenge	RII (%)		Rank
	Magnitude of Challenge	Significance of Challenge	
Client uncertain about project requirements	91.25	82.50	1
Limited time given for the appraisal/short deadlines by the client	82.50	83.75	2
Estimating the sales growth up to the completion of project	82.50	82.50	3
Estimating the rental growth up to the completion of project	80.00	88.75	4
Estimating the timing of cash inflows and outflows	76.25	86.25	5
Estimating/forecasting skills requirement	76.25	80.00	6
Client influencing outcomes to satisfy other parties	73.75	80.00	7
Estimating the future inflation rate	73.75	78.75	8
Obtaining rental values/rates from similar projects	72.50	86.25	9
Estimating discount factor (Cost of capital)	72.50	80.00	10
Availability of the development period (total time)	71.25	83.75	11
Availability of the basic specifications of the project	66.25	77.50	12
Obtaining investment yields (return on capital/funds)	66.25	76.25	13
Obtaining building cost data (similar projects or otherwise)	65.00	78.75	14
Presenting and communicating the outcomes/results	65.00	75.00	15
Selecting a suitable technique	63.75	78.75	16
Estimating building costs	61.25	81.25	17
Availability of profit percentages	60.00	75.00	18
Adjusting rent values/rates	58.75	80.00	19
Adjusting building costs	57.50	86.25	20
Obtaining sales values from similar projects	56.25	80.00	21

4.3. *ANALYSIS AND DISCUSSION OF THE KEY CHALLENGES*

Development appraisals are commissioned at an initial stage of the development process and at this stage it cannot be expected the client to have a comprehensive or fixed requirement. Client requirements would change due to availability of new information, changes in market and economic conditions which are reasons for the top ranked key challenge. Changes would also require additional time to be incorporated and thus since time is also limited (2nd key challenge) it would make it further challenging. Due to this uncertainty of requirements it would also affect the availability of the development period, the basic specifications, profit percentages and selection of a suitable technique which are the 11th, 12th, 18th and 16th ranked key challenges. As found previously the respondents' frequency of usage of risk analysis techniques are not high (Refer Section 4.1) and a major reason for this can be the limited time available (2nd key challenge) to do a risk analysis which is only a supplementary task.

The sales and rental growths (3rd and 4th key challenges) would depend on external factors such as general economic conditions, market conditions, customer preferences, government influences etc. This is further complicated due to the nature of the property market and construction industry explained in Section 2.5. Growth rates can be obtained by extrapolating and analysing historical data. Since estimating growth rates are a major challenge it would mean that historical sales and rental value data is of less importance to predict the future due to the dynamic nature of Sri Lankan market or even mean that there are no sufficient and relevant data available. This contrast with the situation in the UK as stated by Morley (2002) that compared to the 1990's the uncertainties which pervade predictions of rental growth and cost inflation had been reduced. Estimating future inflation was ranked as the 8th key challenge which shows that the Sri Lankan situation is not comparable to that of the UK.

The timing of cash flows is needed when using the discounted cash flow technique. Since the availability of the development period is also challenging due to uncertainty and unavailability (11th key challenge) this would affect the estimation of the timing of cash flows (5th key challenge).

A development appraisal in itself can be known as an estimate or forecast. And as explained in Section 2.5, property markets are imperfect in nature with the lack of perfect information which is further magnified by its dynamic and unpredictable nature. All these factors would make estimating very challenging which will require a considerable estimating skill from an appraiser (6th key challenge). The challenge of estimating building costs (17th key challenge) compared to other estimating related key challenges (3rd, 4th, 5th, 8th and 10th ranked) at the lower end of the ranking. A reason for this would be the availability of cost databases that would make estimating building costs less challengeable.

Development appraisals are required to obtain finance and if the outcome is not favourable financing institutions would not be willing to provide finance for the development project. Therefore clients may have a tendency to impact on the development appraisal to show improved results (7th key challenge). A reason for the 15th ranked key challenge would be due to the lack of time given to the appraisal (2nd key challenge) which would mean that limited time would be available for comprehensive and attractive presentation material to be prepared.

4.4. Solutions for Challenges in Conducting Development Appraisals in Sri Lanka

Section four of the questionnaire (Refer Section 3.3) contained 13 main solutions identified through the literature review which were required to be rated by the respondents as ‘very low’, ‘low’, ‘medium’, ‘high’ or ‘very high’. These points were assigned values of 1, 2, 3, 4 and 5 respectively to calculate RII.

Table 2: Ranking of the Importance of Solutions for Challenges in Conducting Development Appraisals

Solution	RII (%)	Rank
Detailed market research activities to obtain rent and sales data	88.75	1
Maintaining internal building cost databases	85.00	2
Use of risk analysis techniques	83.75	3
Recording of past project details	80.00	4
Hiring marketing, advertising consultants and obtaining data	72.50	5
Upward adjustment of costs, cost of capital, investment yield	71.30	6
Hiring market research firms and consultants	70.00	7
Use of contingency sums	70.00	7
Use of standard methods and formats (Internally developed)	63.75	9
Developing customised software packages for development appraisals	60.00	10
Use of guidebooks and manuals of development appraisals	56.25	11
Use of RICS code of measurement	50.00	12
Purchasing development appraisal software packages	47.50	13

4.5. Roles of the Quantity Surveyor in Development Appraisals in Sri Lanka

Section five of the questionnaire (Refer Section 3.3) contained 14 main roles of a QS identified through the literature review. The values given to the ratings and the procedure followed to calculate the RII is similar to that given in Section 4.5. However this was a 6 point Likert-type scale which consisted an additional point to indicate the role not being carried out by a QS in the respondent’s organisation. This point was assigned a value of 0 for the calculation of the RII. The results are given in Table 3.

Table 3: Ranking of the Frequency of Roles carried out by a QS during Development Appraisals

Roles	RII (%)	Rank
Providing building/construction costs data	97.78	1
Calculating the net lettable areas of the building	82.22	2
Determining the timing of cash inflows and outflows during construction period	68.89	3
Determining professional fee percentages	68.89	3
Determining the duration of construction	53.33	5
Calculating the discount factor (Cost of capital/cost of funds)	42.22	6
Arriving at rental values/rates for the project	33.33	7
Determining finance costs/interest rates and funding fees amounts	31.11	8
Conducting the whole development appraisal	28.89	9
Calculating the investment yield	24.44	10
Estimating the inflation rate	22.22	11
Arriving at the selling prices of units	20.00	12
Estimating the rental growth and sales growth rates	20.00	12
Determining sales/ promotional costs, letting fees	17.78	14

The main role of a QS when conducting development appraisal is providing building cost data. This confirms with the main roles of a QS given by many authors as roles dealing with construction costs (Ashworth and Hogg, 2002). Roles ranked from 1 to 5 have a RII of more than 50% and these would be relatively more frequent roles carried out by the QS. These roles are related to construction and can also be grouped as falling into the expenditure side of a development project. The 7th, 10th, 12th and 14th ranked roles fall into the revenue side of a development project. This shows that the QS's involvement in the revenue side is lower.

These roles can be linked to some of the challenges given in the questionnaire. Since the respondents also rated the significance of each challenge to the development appraisal process and outcome, from the ranking of challenges based on their significance it can enable to identify whether a given challenge is of higher importance to the appraisal process and outcome to determine whether the role is of importance.

For the top role of providing building/construction cost data challenges linked are adjusting building costs (RII of 86.25%, refer Table 1) and estimating building costs (RII of 81.25%, refer Table 1) which were ranked as 2nd and 9th based on the significance of challenge. Thus, the top ranked role carried out by the QS is of very high significance to the development appraisal process and outcome. A reason for this is that building/construction cost amounts to a very high percentage of the total costs of a development project. For the 3rd ranked role of determining the timing of cash flows during the construction period the linked challenge is estimating the timing of cash inflows and outflows (RII of 86.25% refer Table 1) was ranked as the 2nd based on the significance of challenge. This is another important role carried out by a QS. The 4th ranked role of determining professional fee percentages links to challenges of obtaining professional fees (RII of 51.25%) and adjusting obtained professional fees (RII of 55%) which were ranked as 37th and 35th based on the significance of challenge. Therefore, this role however is not relatively important.

Out of the respondents' whose organisations employed QS's (33%) rated as the QS not conducting the whole of the development appraisal. This would mean that a higher percentage (66%) have had conducted the whole of the development appraisal even though the frequency of carrying that role is low with an RII value of just 28.9%.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

With the use of discounted cash flow methods it would enable an additional benefit of the ability to use investment appraisal tools such as IRR and discounted payback period which are also useful to consider the viability of a project.

The use of the residual valuation technique in Sri Lanka is not popular. Since this technique has limitations and drawbacks and had been criticised, the lack of usage is acceptable. From this technique the price for the land can be calculated and if this technique is rarely used then it can be concluded that a main objective of development appraisals in Sri Lanka is not to find the land value. Risk is part and parcel of property development. Development appraisal is used in the property development sector and also since it is used from the initial stages of a project risks would be immense. Therefore the use risk analysis techniques to support development appraisals are of paramount importance

Out of the 21 key challenges, 6 challenges (29%) were related to estimating and therefore it can be concluded that estimating skill is vital when conducting a development appraisal. If the clients influence is significant enough to vary the integrity of the outcome then there is a huge risk that Sri Lankan appraisers and even clients would also encounter a negative reputational impact which happened in the UK (Refer Section 2.1).

A development appraisal requires many inputs which can be viewed as revenue and expenditure related. The majority of expenditure related amounts come from construction related tasks. The major role of a QS when conducting development appraisals in Sri Lanka is to provide building cost data. This confers to the scope and expertise of a QS as an expert and professional dealing with construction costs.

As discussed in Section 4.5, the most frequent roles carried out by the QS of providing building cost data and determining the timing of cash flows during construction have a high importance to the appraisal process and outcome and thus it can be concluded that a QS's contribution is important. As given in prior Section 2.6, many quantity surveying firms have extended the service of development appraisals to clients. In the Sri Lankan context this can be seen from the findings however the frequency of doing development appraisals are low.

5.2. RECOMMENDATION OF SOLUTIONS FOR KEY CHALLENGES

Several top ranking key challenges falls under client's pressure and influence. Solutions that an appraiser can take in these situations are to maintain and adhere to professional ethics and standards in order to maintain the integrity and objectiveness of the development appraisal. For the limited time available it is recommended to use customised software packages, computerised networks between stakeholders such as intranet for speedy communication and maintain consistency across workings and the like to reduce the time for appraisals.

Estimating sales and rental growth had been identified as the 3rd and 4th ranked key challenges. Therefore, for this it is highly recommended to conduct detailed market research activities (Top ranked solution with a RII of 88.75% as given in Table 2) and not to solely rely on historical data.

Even though the use of risk analysis techniques have been identified as the 3rd ranked solution with a RII value of 83.75% by the respondents (refer Table 2), in practice risk analysis techniques does not seem to be highly used (Refer Section 4.2). Therefore it is highly recommended to frequently use risk analysis techniques when conducting development appraisals. Simple risk analysis techniques such as upward adjustment of costs, cost of capital, investment yield (6th ranked solution) and use of contingency sums (7th ranked solution) are also recommended. However, they are recommended to be used in scenarios where time is limited and more encouragement is given to use proper risk analysis techniques such as sensitivity analysis etc.

Maintaining internal cost databases had been rated by the respondents as the 2nd ranking solution with a RII of 85% (refer Table 2). This shows the awareness of the importance of having cost databases and might even be a reason for the relative reduction of ranks for obtaining and estimating building costs compared to that of the revenue side. Therefore it is highly recommended to create, update and improve data bases containing economic, revenue and financial data as well.

5.3. RECOMMENDATIONS FOR QUANTITY SURVEYORS

Management and financial type companies have economic data, sales, rental data and other financial related knowledge which would be needed when conducting a development appraisal. Since the roles related to the revenue side of the development appraisal done by a QS are low, this statement can be justified (refer Table 3). Therefore, it is recommended for quantity surveying firms to enhance their databases and focus on collecting the above mentioned additional data.

It is also recommended to develop, practice and enhance estimating skills since these were found as the core skills required for a development appraisal in order to deal with the many of the key challenges.

Development appraisal is not an individual person's work and it requires inputs from a wide array of parties and professionals and thus it would not be wise to conclude that the QS is the most suitable person to do a development appraisal. Each project would be unique and would demand special features and thus the development appraisal needs to acquire inputs from the different parties. It is teamwork where it is recommended as a professional to develop networking skills, obtain the inputs from the most suitable/competent person and also to respect each person's input and perspective.

As found out from this research the client influence and pressure related challenges are top ranked key challenges. This influence would tamper the professional judgement and decisions of the appraisers and even a QS's. A QS is a professional and would be obliged to behave ethically. Therefore, it is highly recommended for the QS as well as appraisers to maintain integrity and objectivity when conducting development appraisal to avoid any risk of damage to the organisation and the profession as overall. It is further recommended to adhere to ethical codes and standards issued by professional bodies.

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LIFE-CYCLE ASSESSMENT FOR CONSTRUCTION PROCESSES IN BUILDING CONSTRUCTION: A PROPOSED CONCEPTUAL FRAMEWORK

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ABSTRACT

Life Cycle Assessment (LCA) is a powerful tool which can be used to analyse the environmental effects associated with buildings. Even though there are numerous LCA studies carried out on buildings only a handful of studies have concentrated on the construction phase of buildings. The few studies that have considered the construction phase have been reluctant to investigate commercial buildings largely due to lack of data. Most of the studies either ignore or approximate the effects of the construction phase, stating the insignificance of them compared to the total environmental impacts of a building over its life cycle. Many studies have concluded a total effect of 3 to 11percent in the construction phase compared that to the total effects. However, the large impacts at an aggregate level that would concern the designers and the builders have been ignored by these studies. Thus this paper attempts to comprehensively analyse the significance of the construction phase and suggest a methodology for analysing the environmental effects in the construction phase of a building. The outcome of this paper would provide a guideline for the researchers to concentrate on the construction phase in their analyses.

Keywords: *Buildings; Construction Management; Construction Process; Environmental Emissions; Life Cycle Assessment.*

1. INTRODUCTION

Environmental impacts associated with buildings are one of the major concerns that govern the research interest around the globe. Almost all the phases of a building (Guggemos, 2003; Mao *et al.*, 2013) (from the design phase to the end of life phase) contribute to a considerable amount of environmental impacts throughout its life cycle. Most of the studies have categorised the life cycle of a building into material acquisition, construction, operation and end of life when evaluating these environmental impacts (Acquaye and Duffy, 2010; Guggemos, 2003; Junnila *et al*., 2006; Mao *et al*., 2013).

In spite of a well-defined Life cycle, Life Cycle Assessment (LCA) of a building is often associated with three major issues, i.e., defining the scope and the system boundary, creating a reliable inventory, identifying the most important impact factors for impact assessment. The first issue is the difficulty of defining a proper system boundary for the analysis. The high complexity and difficulty of data acquisition has restricted most of the studies to concentrate on selected life cycle phases although there have been attempts to assess the environmental impacts for the whole life cycle (Guggemos and Horvath, 2006; Junnila *et al*., 2006). The second issue of not having a sound inventory pressurises the researchers to concentrate on some components or life cycle phases. The main reason for not having a complete inventory can be due to the difficulty of acquiring data of all the phases in the building with a limited amount of time. The final issue is identifying which impact factors are most suitable when LCA in built environment is concerned. Usually most of the studies only considered greenhouse gas emissions in their analysis. These studies have ignored emissions such as particulate matter, nitrous oxide compounds and sulphur dioxide compounds which are common emission elements in construction phase. However careful assessment of each issue to properly address the research requirement will pave the way to a complete analysis with reliable results. Although a handful of studies have made attempts to evaluate the environmental effects of whole life cycle -of commercial buildings (Guggemos and Horvath, 2006) many studies have concentrated only on selected life cycle phases of a building. For instance, one study considered only on the effects of construction materials (Chau *et al*., 2007) while other studies focused on embodied energy use in buildings

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(Chang *et al.*, 2012; Chen *et al.*, 2001) while some analysed embodied energy and operational energy (Yohanis and Norton, 2002) others analysed greenhouse gas emissions (Chau *et al*., 2012, Mao *et al*., 2013, Seo and Hwang, 2001, Suzuki and Oka, 1998).

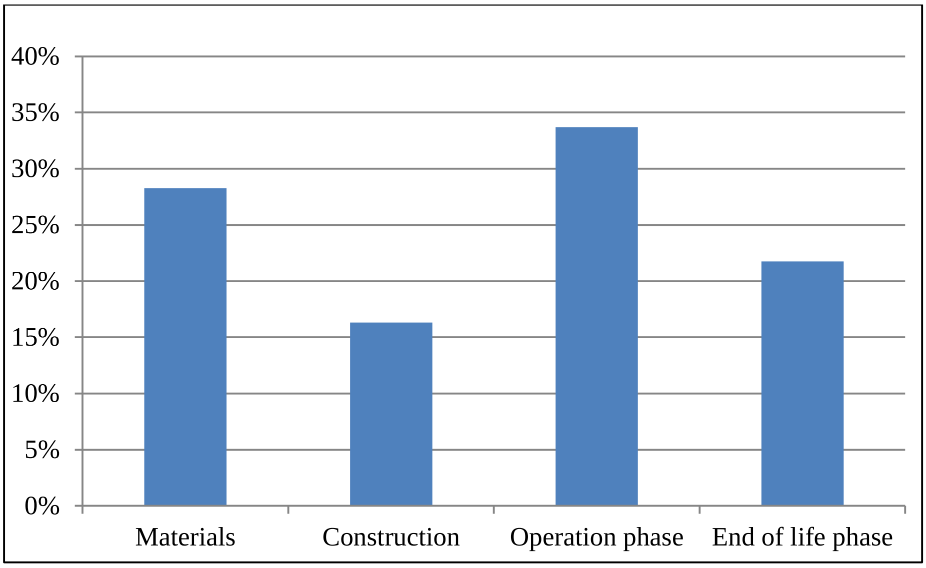

Figure 1: Distribution of Each Phase of a Building Used in Different Literatures

It is evident that (refer Figure 1) most of the studies have ignored environmental effects of the construction phase based on the approximation that the impacts are too small. Usually the studies conclude that construction phase encounters for 3-11percent (Junnila and Horvath, 2003) of the total impacts over the life cycle. The main reason for the low percentage figure is that the construction period (Usually 1 to 3 years) is relatively shorter when compared to the considerably long (Around 50 years) use phase. Since the results in Figure 1 shows the lack of concern given towards the environmental impacts of construction phase it draws the concern of the significance of evaluating the impacts of construction phase. Analysis of environmental impacts is of greater importance to the designers and contractors. The results will provide guidance to the designers and the contractors to adopt a more environment friendly construction techniques and designs. It would enable the designers and the builders to make critical decisions on the performance of current techniques and possible methods of improvements in order to minimise the environmental impacts in the construction phase.

2. LIFE CYCLE ASSESSMENT

Life cycle assessment is known to be a technique that has been widely used to measure and compare environmental impacts of a certain product or process. Thus, LCA can evaluate the environmental impacts of a building from cradle to grave. A researcher would have to analyse the effects of raw material acquisition and manufacture, construction, use and operation, maintenance and repair and end of life. According to ISO 14040, four steps are required to carry out a typical LCA study. The first step discusses how to define the goal and scope for the study. This step is one of the most important steps as it critically identifies the possible system boundary and objectives of the analysis which will draw the initial research framework. Proper identification of goal and scope is crucial in built environment because of the practical difficulty of including all the activities associated with building into the analysis. Thus, as the standard explains, the exclusion of certain activities is possible as long as proper justification is made for. Therefore it is important to initially identify the activities which critically contribute towards environmental effects for the analysis.

The second stage in the four step procedure is as important as the first stage as it includes the inventory phase. Typically this inventory phase includes interpretation of system boundary with the corresponding unit processes, collection of data and summation of the total impacts across the whole process which is under consideration. Life cycle inventory (LCI) stage uses three major LCA methods, input-output based LCA and process based LCA and hybrid based LCA to evaluate the environmental effects. Input-output based LCA is a top down economic technique which uses national average data of each sector in an input-output matrix for calculating the impacts (Acquaye and Duffy, 2010; Treloar, 1997). This method has inherent limitations like age of data, use of national averages, proportionality assumption and homogeneity assumption etc. (Crawford, 2008; Hendrickson *et al*., 1997; Lenzen, 2000).

Process based LCA method is the most commonly used method (refer Table 1) by most of the researchers across the globe for evaluation of environmental impacts (Acquaye and Duffy, 2010; Chau *et al.*, 2007; Chau *et al.*, 2012; Mao *et al.*, 2013). The main reason is that process based LCA makes it easier to address the model and the system boundary as long as enough data is available for analysis. Process analysis collects environmental inputs for all activities in a process to evaluate the environmental impacts in the form of output. Therefore the accuracy and the reliability of the analysis mainly depend on the quality and the accuracy of the input data used for the analysis. Unavailability of enough quality data has always been a major issue when adopting process analysis in built environment. It also suffers from limitations such as issues with system boundary, data accuracy and reliability and upstream truncation errors etc. As long as the quality, accuracy and availability of data can be assured process analysis is the most accurate method available for analysing environmental impacts (Hendrickson *et al*., 1997).

Hybrid based LCA method is a combination of both process method and input-output method. The main objective of combining the two methods is to utilise the advantages inherent to both the methods while trying to minimise the limitations associated with each method. Process based hybrid method and Input-Output based hybrid method are the two hybrid methods which are in use. Process based hybrid analysis uses input-output data in the upstream stages to minimise the limitation of truncation errors at the upstream stage inherent with process analysis and uses process based data in the downstream stage (Bilec *et al.*, 2009; Chang *et al.*, 2010; Chang *et al.*, 2012; Dong *et al*., 2013). This method is useful when the whole life cycle of the building is analysed because it's the upstream data (data on material acquisition and production) which are hard to collect. On the other hand, input-output based hybrid analysis initially uses available process based data to build the inventory and remaining gaps created are filled by input-output data. This method was initially implemented successfully by Graham Treloar (Crawford, 2008; Treloar, 1997) in the field of construction and found out to be more effective when accuracy of data is limited and studies have shown that it exhibits only 20% of incompleteness (Crawford, 2008) in embodied energy evaluation.

Table 1: Matrix Analysis of Selection of Different Methods and Life Cycle Phases by Different LCA Studies Related to Buildings

Method of analysis	Material extraction	Construction	Use and Maintenance	End of Life
Input-Output Method	1. (Seo and Hwang, 2001) 2. (Su *et al*., 2010) 3. (Chen and Zhang, 2010) 4. (Kok *et al*., 2006)	1. (Seo and Hwang, 2001) 2. (Chen *et al*., 2011) 3. (Su *et al*., 2010) 4. (Chen and Zhang, 2010)	1. (Seo and Hwang, 2001) 2. (Chen *et al*., 2011) 3. (Su *et al*., 2010) 4. (Chen and Zhang, 2010) 5. (Kok *et al*., 2006)	1. (Seo and Hwang, 2001) 2. (Chen *et al*., 2011) 3. (Su *et al*., 2010) 4. (Chen and Zhang, 2010)
Process Method	1. (Guggemos, 2003) 2. (Guggemos and Horvath, 2006) 3. (Chau *et al*., 2012) 4. (Yohanis and Norton, 2002) 5. (Citherlet, 2001) 6. (Xing *et al*., 2008) 7. (Treloar *et al*., 2003) 8. (Huberman and Pearlmutter, 2008) 9. (Verbeeck and Hens, 2010) 10. (Junnila and Horvath, 2003) 11. (Junnila *et al*., 2006) 12. (Mao *et al*., 2013) 13. (Monahan and Powell, 2011) 14. (Chau *et al*., 2007) 15. (Junnila and Horvath, 2003) 16. (Kua and Wong, 2012)	1. (Guggemos, 2003) 2. (Guggemos and Horvath, 2006) 3. (Mao *et al*., 2013) 4. (Chen and Zhu, 2008) 5. (Citherlet, 2001) 6. (Li *et al*., 2010) 7. (Junnila and Horvath, 2003) 8. (Kua and Wong, 2012) 9. (Li *et al*., 2010)	1. (Guggemos, 2003) 2. (Guggemos and Horvath, 2006) 3. (Chau *et al*., 2012) 4. (Yohanis and Norton, 2002) 5. (Citherlet, 2001) 6. (Xing *et al*., 2008) 7. (Treloar *et al*., 2003) 8. (Verbeeck and Hens, 2010) 9. (Junnila and Horvath, 2003) 10. (Junnila *et al*., 2006) 11. (Kua and Wong, 2012) 12. (Li *et al*., 2010) 13. (Mao *et al*., 2013) 14. (Monahan and Powell, 2011) 15. (Chau *et al*., 2007) 16. (Junnila and Horvath, 2003) 17. (Kneifel, 2010) 18. (Kua and Wong, 2012) 19. (Li *et al*., 2010) 20. (Yohanis and Norton, 2002) 21. (Yan *et al*., 2010) 22. (Yu *et al*., 2011) 23. (Xing *et al*., 2008)	1. (Guggemos, 2003) 2. (Guggemos and Horvath, 2006) 3. (Chau *et al*., 2012) 4. (Mao *et al*., 2013) 5. (Citherlet, 2001) 6. (Junnila and Horvath, 2003) 7. (Kua and Wong, 2012) 8. (Treloar *et al*., 2003) 9. (Verbeeck and Hens, 2010) 10. (Li *et al*., 2010) 11. (Yan *et al*., 2010) 12. (Yu *et al*., 2011) 13. (Xing *et al*., 2008)

Method of analysis	Material extraction	Construction	Use and Maintenance	End of Life
Hybrid Methods	1. (Han *et al*., 2013) 2. (Fay *et al*., 2000) 3. (Chang *et al.*, 2012) 4. (Crawford *et al.*, 2010) 5. (Crawford, 2008) 6. (Dong *et al*., 2013)	1. (Chang *et al*., 2012) 2. (Crawford *et al.*, 2010) 3. (Crawford, 2008)	1. (Han *et al.*, 2013) 2. (Fay *et al.*, 2000) 3. (Crawford *et al.*, 2010) 4. (Crawford, 2008) 5. (Dong *et al*., 2013)	1. (Han *et al*., 2013) 2. (Fay *et al*., 2000) 3. (Crawford *et al.*, 2010)
Number of Studies	**26**	**16**	**31**	**14**

3. PROPOSED CONCEPTUAL FRAMEWORK

Since LCA can be applied to any product or process and hence providing a specific methodology is not practical. This is because each method of analysis carries its own steps of analysis. Input-output analysis requires monetary values with respect to the product under consideration while process analysis will require only the life cycle details of the product and hybrid methods require both the details (Bilec *et al.*, 2009; Chang *et al.*, 2010; Chen and Zhang, 2010; Hendrickson *et al*., 1997). Even within the same analysis method, the product or process which is being evaluated will determine the steps of analysis. A general framework along with the usual steps would provide a basis for anyone who intends to undertake LCA in the built environment. This chapter discuss about the issues that are likely to encounter when developing a proper framework for methodology and flowchart procedure which provides a general guideline in proceeding with the analysis.

3.1. SELECTION OF SYSTEM BOUNDARY AND THE METHOD OF ANALYSIS

The life cycle of a building includes four major stages as shown in Figure 2. The major objective of this paper is to suggest a methodology to critically analyse the impacts in the construction phase. Hence the focus of interest in this LCA should be the construction phase of the building. This construction phase should ideally include material, labour and equipment transportation, material usage, construction equipment usage such as diesel consumption and combustion emissions, electricity usage at site, water usage at site, possible repair and maintenance of vehicles and equipment (Mao *et al.*, 2013). Analysis of these activities in the construction stage would draw more comprehensive results within that stage. Therefore the boundary should be selected to include the above activities which would result in a more comprehensive analysis in the construction stage.

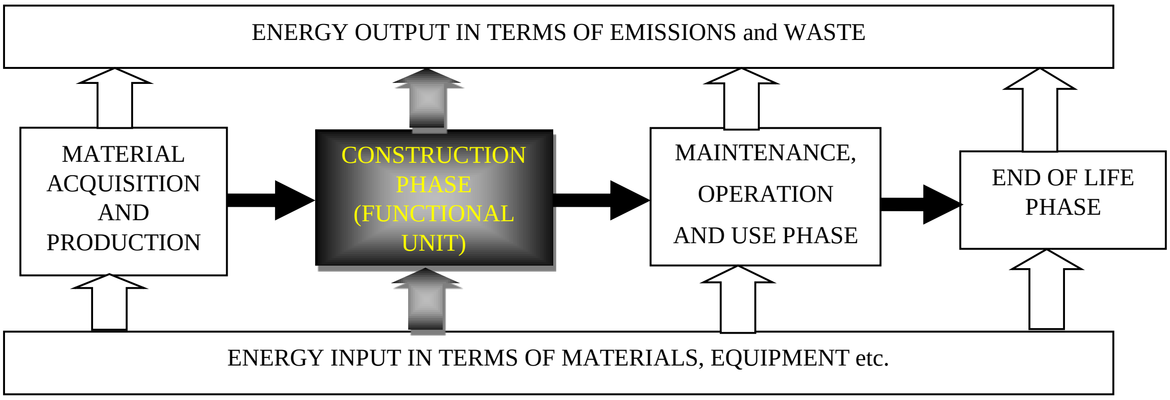

Figure 2: The Life Cycle of a Building (Guggemos, 2003)

Once the activities are selected it is important to select the method of analysis. When built environment is considered the selection of analysis method depends upon the data quality and availability, time consideration and personal choice. Out of the three methods available process analysis and hybrid analysis can be used effectively to analyse the effects in construction phase. The use of process method solely based upon the data quality and the way in defining the boundary for the analysis. A summarised process diagram with the main activities in a construction stage given in Figure 3 explains the necessity of proper data for the analysis. If quality data is available process based LCA can be used for the analysis. If process data is unavailable for all the activities considered in the system boundary, the completeness of the analysis would be an issue and hybrid methods would make a perfect method of analysis in that situation. Another concern is that whether to analyse the whole life cycle of the building or certain selected life cycle phases. Undoubtedly analysis of whole life cycle would draw complete analysis results but with restrained time schedule and data acquisition restrictions may limit the analysis to concentrate on certain phases of a building. But if only some phases are included for the analysis it is important to justify the choice with appropriate reasoning as one can argue that analysis of only certain phases would provide distorted results.

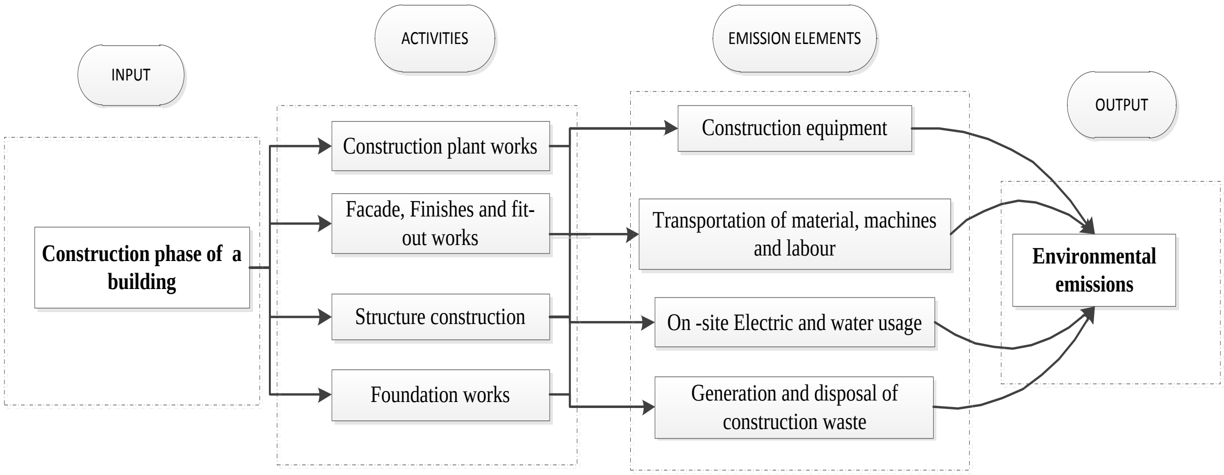

Figure 3: A Presentation of Construction Phase with Associated Environmental Emissions

3.2. *Software Selection and Issues*

The next issue is the selection of ideal software for analysis. A number of software is available for performing LCA. But selection of the software depends upon several factors such as easiness in modelling the process, availability of quality inventory in the database, data relevancy to the geographical location where the project is undertaken, availability of other in built statistical analyses and ability to convert results into presentable outcomes. This section will provide a brief review of four available analysing tools with the advantages and disadvantages inherent with it.

Table 2: Advantages and Disadvantages of Available LCA Tools

Name of Software	Advantages	Disadvantages
SimaPro	– International databases such as eco-invent is available and hence can be used in many countries – User friendly and self-explanatory – There is a possibility for advanced results analysis – Report maker plug-in allows the model to link with MS word and excel – All life cycle stages of a product can be analysed	– None of the databases in SimaPro provides data for on-site construction processes – Unless a user defined process is available it is difficult to analyse – Cannot be used for hybrid based LCA model – Time consuming
Gabi	– Easier to model the process in to the system – Can include effects due to noise as well – Enables to track cost factors as well along the life cycle of the process – All life cycle stages of a product can be analysed	– Database is mainly based in Germany – Issues with the applicability of databases in different countries – Less amount of data is available for on-site construction processes – Limited construction activities are available
BEES	– Combines an environmental score and an economic score to provide a final score – All life cycle stages of a product can be analysed – Focus mainly on effects due to construction	– Cannot be used for hybrid based LCA model – Lot of uncertainty in data

Name of Software	Advantages	Disadvantages
Athena	– The best construction specific tool compared among the others – Allows to analyse the elements of a building separately – Representation of results is simple and understandable – Number of Impact categories are available – All the life cycle stages can be analysed	– Applicable to only American context – Although defined as a construction specific tool, it does not cover every aspect of the construction stage

3.3. STEPWISE PROCEDURE

The whole LCA is an iterative process and hence adopting a systematic procedure would be extremely difficult. In such cases, the ideal way to carry out such an analysis is to follow a stepwise flowchart process. The framework provided by the international standard ISO 14040, would only provide a broader framework which needs further expansion. A conceptual framework as shown in Figure 4 gives a general guideline for carrying out analysis is which can estimate the environmental emissions in construction phase. The entire procedure can be classified into three distinct stages. The initial stage is about developing a framework that will provide a strong foundation in carrying out the analysis (Dixit *et al*., 2013; Rebitzer *et al*., 2004). This includes proper identification of goal and scope, drawing the system boundary and creating a methodological framework. This initial stage focuses on one of the most important aspects of the whole analysis which is defining the functional unit. This functional unit if not defined accurately can provide seriously distorted results which will misinterpret the whole analysis (Rebitzer *et al*., 2004). Functional unit will provide the basis of analysing and comparing the outputs of a process or product through its input. LCA in construction usually address the functional unit as amount per area (Guggemos, 2003; Sihabuddin and Ariaratnam, 2009). Another activity in the initial stage which needs careful attention is development of system boundary. The life cycle of a building includes a number of phases which includes a large number of activities which might be difficult to analyse. Even in a concerned phase there are a large number of activities that are practically not possible to analyse at a given stretch. Hence it is important to identify the most crucial activities that contribute to environmental emissions and draw a system boundary around with stating the limitations of the drawn system boundary with accurate justification. Next step includes originating a framework for the method of analysis. In this step it is required to identify the activities inside the system boundary that may have significant contribution towards environmental emissions. This will simplify the analysis because including all the activities inside the system boundary will not only make the analysis more complicated but also will have less effect on the total environmental effects. Final step of the initial stage is to select the method of analysis. Selection of a method requires intensive literature review and data availability. If enough data is available it is always advisable to adopt process analysis as it will provide more comprehensive results. For a comprehensive analysis it is important to define the initial stage precisely as the accurate outcome of other stages solely depends upon the completeness of this stage.

The next stage includes data collection and identification of impact indicators for the analysis. The entire analysis depends upon the data collection because lack of quality data will draw weak conclusions with a lot of inaccuracies. Data collection should be carried out with careful attention and need to make sure that all the sufficient data is collected to evaluate the environmental impacts. Often LCA software includes different impact indicators in impact assessment. Although there are several impact indicators it is important to identify the relevant indicators when construction is considered. Although the middle stage is not important as the initial stage it requires a considerable amount of time and the quality and the validity of the inventory will decide the effectiveness of the entire analysis. In such cases where failure to establish a quality inventory, it is important to repeat the initial stage either by reforming the methodological framework or by changing the method of analysis.

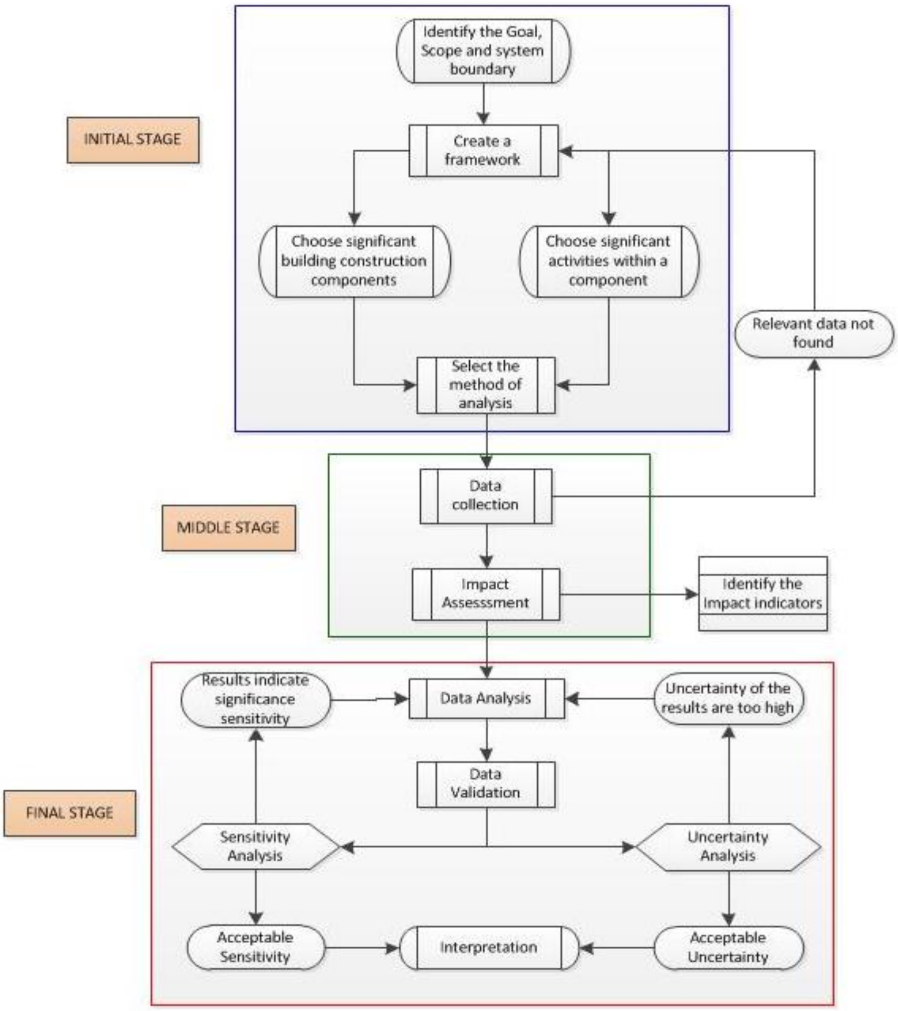

Figure 4: General Methodology for Carrying Out LCA in Buildings

The final stage is as important as the initial stage as it will provide the results of the modelled analysis. Usually this consumes a considerable amount of time as this is an iterative process. Selection of software depends upon the availability, relevancy, easiness and personal preference. LCA in construction is often faced with the difficulties of lack of available data in software databases. In such cases before commencing the analysis it is required to update the database with the required data. This may require intense data collection and continuous surveys to collect emission profiles of construction equipment and machines. Data analysis will be followed up by data validation which often divided into sensitivity analysis and uncertainty analysis. Sensitivity analysis will check the amount of sensitivity between input and outputs of the analysis (Mattila *et al*., 2013; Mokhtari *et al*., 2006; Savolainen, 2013) while uncertainty analysis will determine the uncertainties associated with data and outputs(Ao, 2011; Sonnemann *et al*., 2003). There are number of sensitivity and uncertainty analysis methods that have been used in various studies in LCA (Ardente *et al*., 2005; Dong *et al*., 2013; Hayes, 2011). Selection of proper method for the consistency checks will reduce the work load and they would also provide a reliable outcome.

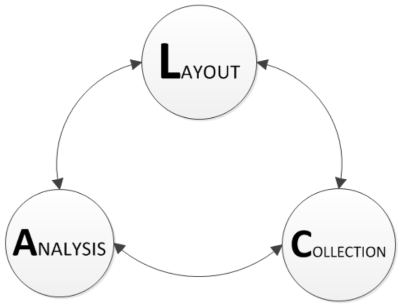

Figure 5: Simplified Methodology (Thumb Rule) for Carrying Out LCA

The methodology for carrying out LCA can be put into general terms of Layout, Collection and Analysis where layout represents creating a methodological framework with identifying scope and the system boundary while collection represents data collection and development of the database. Analysis represents data analysis and reliability checks to validate the results.

4. CONCLUSIONS AND SUGGESTIONS

The significance of analysing environmental impacts in construction phase is highlighted in this paper. It is evident that analysis of impacts in construction phase is an area which has been largely less emphasised by researchers and industry practitioners. Negligence of assessment of environmental impacts in construction phase is due to complexity, time consuming nature and difficulty in acquiring data. In spite of these limitations a proper system boundary and a well-defined scope would reduce the complications associated with the analysis. To draw the best out of the analysis it is important to identify the system boundary as it will highlight the results of the concerned phase rather than outlining the whole scenario. Ideally the assessment of environmental impacts in construction phase should include the impacts of machines and equipment use, impacts due to transportation, maintenance and repair works of machines and equipment and material consumption. Although greenhouse gas emissions is the governing impact indicator related to construction if other indicators such as water and land usage, dust generation can be included in the analysis the results would be more comprehensive. The paper proposed a conceptual framework on how to measure the environmental impacts of construction activities. The methodological framework can be used to develop a toolkit that is able to capture the environmental impacts in construction phase. This will benefit the designers and the contractors to optimise the design process.

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LIVING IN LOW INCOME CONDOMINIUMS: END USERS' PERSPECTIVES

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ABSTRACT

The demand for low income condominiums in the city of Colombo has gradually increased in the past few decades in order to provide accommodation for low income earners and resettlement of shanty dwellers with the upsurge of land values in urban areas. Living in a condominium is considerably different from living in a sovereign house. In a condominium, personal ownership is limited to interior of the unit and requires sharing responsibilities with all the unit owners for the exterior of the complex. Identifying the issues in condominiums which have been designed for the low income community is essential to provide better living environment. Thus, it is vital to identify the satisfaction level of occupants who are settled in low income condominiums with respect to their living condition. Therefore, this study aims to fill the existing research gaps by investigating the existing living condition of condominiums which designed for low income families in terms of user satisfaction. First, a literature survey was carried out. This was followed by a comprehensive questionnaire survey as the data collection technique. Data were collected addressing the satisfaction on living condition under five main areas namely; social condition, facilities availability, management and maintenance of facilities, design and construction, and legal aspects. The results were analysed calculating the percentage values of each aspect. It was identified that 12% of occupants were only satisfied with the social condition in condominium living. In terms of satisfaction level on facilities availability, electricity, telecommunication and water received the highest percentage that is 65%, 62% and 57 % respectively. Moreover, the survey results show that occupants are dissatisfied with quality of construction work, maintenance and management aspects. Less awareness about the legal aspects was another issue among the occupants. Finally, this study suggested conducting post occupancy evaluation will provide stable and sustainable environment for future condominium developments.

Keywords: *Condominiums; Living Condition; Low Income Families; Satisfaction Level.*

1. BACKGROUND TO THE RESEARCH

There is a significant demand for condominiums in Colombo metropolitan area due to high population density, scarcity of land availability and soaring prices of property particularly in urban areas of the country (Gunawardena and Samarajeewa, 2006) and convenience of buying a condominium rather than constructing a house (Senaratne *et al.*, 2006). Hewamanna (2005) identified that there is a rapid expansion in the construction and sale of condominiums in Sri Lanka during the past few decades. Especially in Colombo and suburbs, the apartment market is mainly vigorous because there is a huge demand for urban living (Wasala, 2007). However, in long-term sustainability of this industry would, certainly, depend on the ability of the property developers to meet the needs and expectations of the end users or the occupants (Gunawardena and Samarajeewa, 2005). Kerti (2014) sated that construction of apartment or condominium is a means of supporting the development options tourism in tourist destination areas which have limited land for construction of tourism facilities. According to the Apartment Ownership Law Act No. 39 of 2003, condominium is a property comprising of land with a building or buildings more than one story and having more than one unit residential or non-residential accommodation.

The population of a country can be generally in three groups according to the income levels as high, medium and low (Central Bank, 2009). The residential sector of Sri Lanka is a major area that shows variations according to the above three levels. Types of the condominium available in Sri Lanka mainly depend on facilities offered such as swimming pool, gymnasium, restaurant and internal and external finishes and

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fittings used. (Senaratne *et al*., 2006). As Wijeyeweere (2004) mentioned, based on the available facilities, finishes and fittings, condominiums can be categorised in to super luxury, luxury, semi luxury and the utility condominiums. The government is the main developer for utility condominiums in Sri Lanka. Therefore, government servants, low-income earners and the shanty dwellers have been the beneficiaries of such state sponsored projects. Siriwardena (2001) stated that low income condominiums have become the most viable alternate homeownership method to provide accommodation for low income earners and resettlement of shanty dwellers with the upsurge of land values in urban areas. Even though living in these condominiums provide many benefits for low income groups in the society, as found by Lorensuhewa (2009) various issues existed with the low income community in Sri Lanka. According to the findings of Gunawardena and Samarajeewa (2005), significant differences could be seen between the expectations of occupants in condominium and understanding of the developers. As stated by the same authors, this situation is more worsen in the public sector condominium developments. Gunawardana and Samarajeewa (2006) pointed out that occupant satisfaction is very significant for the progress and existence of the condominium industry. Therefore, identifying the issues in condominiums designed is essential to provide better living environment for the users although few research studies conducted in the particular area. Thus, this study investigates the existing living condition of low income condominiums in Sri Lanka in terms of user satisfaction. This study was limited to the low income condominiums which are located in the Colombo district.

2. LOW-INCOME CONDOMINIUMS AND USER SATISFACTION

2.1. OVERVIEW OF CONDOMINIUM PROPERTY

Condominium is a different type of ownership created in the 1960s of real property unlike subdivisions which have been in existence for centuries (Lee, 2009). The word condominium is derived from the Latin term “Condo” which means to put or joins together (Ranaweera, 2006). A condominium is a form of home ownership in which individual units of a larger complex are sold, not rented (Pollick, 2009). According to Zulfadzlan (2012), at present, developers are more interested to develop condominiums with many facilities with the upsurge demand for high rise buildings. According to the Colombo Development Plan (CDP), condominium complexes can be grouped into three general architectural types as low rise condominiums, medium rise condominiums and high rise condominiums based on storey height and the building area. Buildings with an area of 150m^2 - 249m^2 with three floors, maximum height of 11.25m buildings categorised as low rise condominiums, area 250m^2- 999m^2 with eight floors, maximum height of 30m buildings categorised as medium rise condominiums and area 1000m^2 - 1999m^2 with 12 floors, maximum height of 45m buildings categorised as high rise condominiums. In today's context, the highest demand is for residential condominiums, which could be subdivided in to super luxury, luxury, semi luxury and the utility condominiums (Wijeyeweere, 2004). Super luxury condominiums consist of the all modern and luxury facilities such as restaurants, swimming pool, gymnasiums and highly sensitive electronic security systems (Ranaweera, 2006). Semi luxury condominiums are getting popular among the migrant workers who could own such unit with their foreign exchange earnings and live peacefully on their return or in their retirement (Wijeyeweere, 2004). Government servants, low-income earners and shanty dwellers have been the beneficiaries of utility condominiums. Most of these condominiums in Colombo have come up as resettlements or as urban renewal programmes carried out by the government (Wijeyeweere, 2004).

2.2. THE CONCEPT OF “LOW- INCOME CONDOMINIUMS”

The term low income condominiums is derived from utility condominiums. Basically, the government furnishes these utility condominiums to provide houses to the government servants and especially resettlement of shanty dwellers and low income earners (Mirihagalla, 1983). The low income families basically identify as families which consisting of five members and whose monthly income is less than Rs. 16,735.00 (Central Bank, 2009). Correspondingly, these families do not have a fixed occupation and live with limited range of necessities. In most of cases, these people represent the lowest community features and majority of them engage in fishery while others are pavement sellers, labourers, day workers and all that lower level hard working people (Lorensuhewa, 2009). In accordance with the Karunaratne (1978) the various settlements of the low income earners in Colombo could be classified in to three categories as follows.

- Old tenement which have been reduced to slum conditions
- Large, old residences in the industrial and commercial areas which have developed into slums
- Shanties

As mentioned in the background, low income condominiums have been developed by the government or any other institutions meant for resettlement of shanty or slum dwellers and for low income families in urban areas. Affordability is very low among the said community. Therefore, acceptable construction quality cannot be expected from those condominiums. However, if quality of construction is not properly controlled it will be a heavy stain for the country (Bandulahewa, 2006). The new condominium registration system is introduced in terms of the Apartment Ownership (Amendment) Act No. 39 of 2003, also made provision to solve problems faced by the property developers in condominium registration. The people who purchase units in a condominium technically own everything from their walls inward. All of the individual homeowners have shared rights to most common areas, such as the hallways, staircases and utility services. Maintenance of these areas becomes the responsibility of a condominium association or management. Every owner owns a share of interest in the condominium association, plus an obligation to pay monthly dues or special assessment fees for larger maintenance problems (Pollick, 2009). This fee covers maintenance, repairs, grounds keeping and building insurance (Cortez, 2009). However, many researches pointed out that several issues accompanied in the low income community regarding their living environment.

2.3. NEED FOR UNDERSTANDING OCCUPANTS SATISFACTION IN CONDOMINIUM LIFE

Satisfaction is referred to as a criterion for evaluating the quality of the residential environment by measuring the effect of perception and assessments of the objective environment upon satisfaction (Altaq and Gzsoy, 1998). As Choudhury (1997) stated residential satisfaction in an apartment is a measure of the capability of the living environment as evaluated by the occupants. It is documented several methods can be used to identify or measure the occupants satisfaction such as formal marketing research, through experience, feedback on the completed projects (Liu, 1999; Ozaki, 2003). Post-occupancy evaluation (POE) is a platform for the systematic study of buildings once occupied, so that lessons may be learned that will improve their current conditions and guide the design of future buildings. Yirga (2012) mentioned that post occupancy management is one of the most pressing challenges with the condominiums as most of the design principles are not well configured and practiced. However, most of property developers seem reluctant to spend much time carrying out such evaluation after a project has been finished. As Gunawardena and Samarajeewa (2006) emphasised, the sustainability of any product lies in its ability to satisfy customer needs continuously. Thus, conducting surveys to identify occupants' satisfaction in condominium life is essential for sustain the properties for a long time.

3. RESEARCH METHODOLOGY

The background study of the research was conducted on a broader perspective to familiarise with the subject area of condominiums, and occupants satisfaction by referring books, journal articles and unpublished dissertations within the research limitations. Kraemer (2002) stated that survey approach is important when research is quantitative and requiring standardised information from and/or about the subjects being studied. Furthermore, survey approach is used where, the views or opinions of many need to be evaluated in order to achieve a firm conclusion. Therefore, survey approach has been selected as the research strategy for this study. The structured questionnaire survey was selected as the most suitable data collection technique. The questioner survey was designed in order to identify user satisfaction in terms of social condition, availability of facilities, management and maintenance of facilities, design and construction, and legal aspects. The structured questionnaires were distributed among a simple random sample of 150 occupants who were living in the ten low income condominiums which aged at least year after occupancy within the Colombo area. The satisfaction level of occupants were identified using the likert scale of 'satisfied', 'satisfied to certain extent' , ' dissatisfied' and ' no idea'.

In this survey, frequency analysis was used to measure the degree of availability and satisfaction for certain aspects in living in low income condominiums in Sri Lankan context and Formula (1) used to calculate figures.

$$\text{Percentage (\%)} = (n/N) \times 100\% \qquad \text{(Eq: 01)}$$

Where: n = Number of respondents, N = Total number of respondents received

4. RESEARCH FINDINGS AND DISCUSSION

The purpose of this research is to evaluate the satisfaction level and the existing living conditions of families who live in the low income condominiums. 120 completed questioners were received from the occupants with response rate of 80% and Formula (1) used to analyse the data. In considering about the general characteristics of respondents, the majority of families had five members (49%) and some of the families had more than five members (4%) in their families. The results showed that 26% of them had four members, 12% of them had three members and 9% of them had less than three members in their families. In considering about the reasons of selecting the condominiums as their living place, the main reason was displacement due to urban development projects. Different psychological, economic and social backgrounds existed among the random sample. The research findings discuss according to the headings included in the questionnaire such as social condition, availability of facilities, design and construction, management and maintenance of facilities and legal aspects.

4.1. SOCIAL CONDITION

During the survey, it was identified that low income families have shifted to condominiums due to resettlement of slums and shanty, displacement due to urban development projects, displacement due to infrastructure development activities and due to resettlement of low income earners. Therefore, it was observed that occupants in low income condominiums were a mixture of different social backgrounds. The breadwinners of most families do not have a permanent occupation. According to the survey results, 26% of them were day workers, 25% of them were engaging in fishing, 18% of them were working as labourers, 8% of them were working as drivers, 7% of them were working as pavement sellers and 16% of them do not have a fixed occupation. Sharing of land, facilities and services, disturbances from others due to loitering and smoking in the common areas and protection of privacy level are some of the complaints made by the condominium users. The data showed that only 12% of occupants were satisfied with the social condition in condominiums as illustrated in Figure 1. Main reasons for their dissatisfaction on social condition were due to not having fixed income and dislike to move with their neighbors who are from different social backgrounds. Moreover, most of the occupants believe that they are not getting enough privacy as a family. Limited face is another issue with them. In addition, they are concerned about sharing common facilities and services which have been misused by some occupants. Thus, except 12 % most of the occupants were not satisfied with their existing living condition according to the facts they have provided.

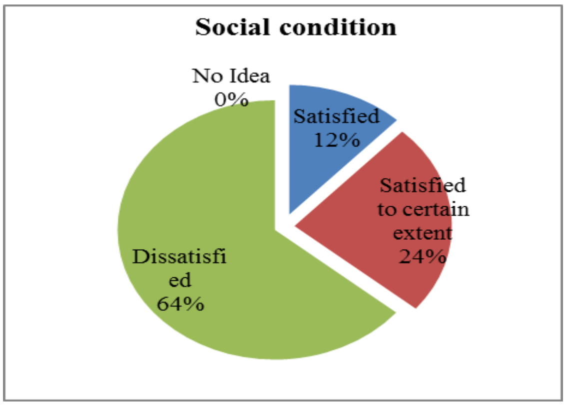

Figure 1: Social Condition

4.2. *FACILITIES AVAILABLE*

The majority of occupants' were occupied in units: the average usable floor area was between 300-600 sq.ft. The facilities available for the low income condominiums have been discussed in terms of accessibility, water, electricity, lighting, ventilation, acoustic, space, health safety and sanitary, waste disposal, telecommunication, security and finally, recreational facilities. Table 1 displays the satisfaction level of occupants on availability and condition of facilities have already identified.

Table 1: Satisfaction Levels on Facilities

Facilities	Satisfied	Satisfied to Certain Extent	Dissatisfied	No Idea
Overall	21%	28%	50%	1%
Accessibility	16%	32%	51%	1%
Water	57%	25%	18%	-
Electricity	65%	28%	7%	-
Lighting and ventilation	23%	24%	50%	3%
Acoustic environment	14%	32%	54%	
Space management	9%	21%	68%	2%
Health, safety and sanitary	8%	30%	62%	-
Waste disposal	8%	36%	56%	-
Telecommunication	62%	18%	20%	-
Security	17%	35%	48%	-
Recreational facilities	6%	33%	61%	-

The following facts were obtained based on the data analysis.

- Satisfaction on accessibility was recognise based on width of corridors, width of stairways, availability of emergency access and disability access. Merely 16% of occupants were satisfied in terms of accessibility. During the survey it was identified that issues with the width of corridors, stairways, and emergency exits. There is no disable access in the many low income condominium design. It was observed, width of corridors and stairways less than 3 feet in most of the condominiums and the occupants claimed that difficulties in carrying goods.
- 57% of occupants were satisfied with water supply system. However, there were few issues with the quality of existing water supply system claimed by the occupants.
- 65% of occupants were satisfied with the electricity distribution and only few of them were not satisfied with the safety features of the electrical system.
- Only 23% of occupants were satisfied with lighting and ventilation. Majority of occupants were not satisfied with the natural lighting and ventilation. Some occupants pointed out that window opening are comparatively small. Sometimes use artificial lighting in dark areas during the day time. It was found, it is an additional cost to their electricity bill.
- Majority of respondents had sufficient telecommunication facilities and only 20% of occupants were facing problems due to the absence of telecommunication facilities. Comparatively, occupants are happy about having such facilities.
- Security is another aspect that has been overlooked in low income condominiums. Only 17% of occupants were satisfied with the available security services. It was observed, the community does not trust each other.
- Since living places are very close to each other, acoustic environment plays a very important role to the lifestyle in condominiums. However, only 14% of occupants were satisfied with the acoustic quality in these condominiums. This is one of the biggest issues faced by them.

- Majority of spaces inside the units have not complied with the minimum space requirement of the family members and 68% of occupants were not satisfied with the space given for them. Some believes, the limited space restrict their freedom, whereas 2% of occupants expressed that they have no idea on space management.
- Most of low income condominiums were operated under very poor health, safety and sanitary conditions. Data show that 8% of occupants were only satisfied on this aspect.
- Occupants' perception on waste disposal facility identified based on availability of sufficient provisions for solid waste disposal, sufficient provisions for waste water disposal, sufficient provisions for sewerage disposal, and sufficient provisions for storm water disposal. Having proper waste disposal system is a basic requirement in a condominium building. However, 56% of occupants were not satisfied with the availability and functionality of solid waste disposal systems and waste water disposal systems. They claimed about the bad smell due to poor maintenance.
- As stated above, people living in condominiums are having limited spaces. Thus recreational facilities have become an essential requirement for the condominiums. However, it was found that 61% of occupants were dissatisfied with the availability and adequacy of recreational facilities designed in low income condominiums.

In general 21% of occupants were satisfied and 28% of occupants were satisfied to certain extent with the available facilities, whereas 50% of occupants were dissatisfied with the available facilities. Only 1% of occupants said that they have no idea regarding the available facilities. It was identified that waste disposal facilities, lighting and ventilation, health, safety and sanitary facilities are some of the important aspects that need to be enhanced in order to provide a healthy living environment for occupants in condominiums.

4.3. MANAGEMENT AND MAINTENANCE OF FACILITIES

Management and maintenance of facilities were undertaken by the Management Corporation (MC) with the contribution of unit owners. However, low income occupants are not financially capable of supporting the management and maintenance activities. Thus, low income condominiums were not properly managed and most of the maintenance activities were not carried out in common areas on regular basis. As a result of this situation 43% of occupants were dissatisfied with the management and maintenance in condominiums as shown in Figure 2. When considering the situation of low income condominiums, many individuals who are assigned for maintenance work were not technically qualified in the field of property management. Thus occupants are not happy with the existing management. Therefore, after handing over the condominium property to the occupants, it is required to establish and implement a proper management and maintenance strategies which is lack in the existing process.

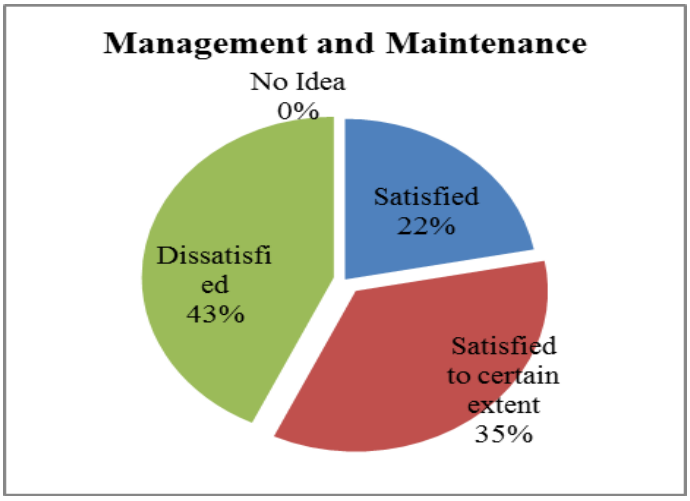

Figure 2: Management and Maintenance

4.4. *QUALITY OF CONSTRUCTION*

Figure 3 illustrates the results of respondents regarding the quality of construction. It was found that many low income condominiums have been built using low quality materials, poor workmanship, and poor supervision especially the condominiums that have developed within the limited time period and limited budget. Accordingly, 37% of occupants were dissatisfied regarding quality of construction whereas 31% said 'no idea' about the construction aspects. Thus, proper procedures should be implemented to safeguard the quality of construction in the future developments within the allocated budget. Thus, it is pertinent to incorporate sustainability practices to support and enhance the basic needs of occupants keeping their satisfaction level.

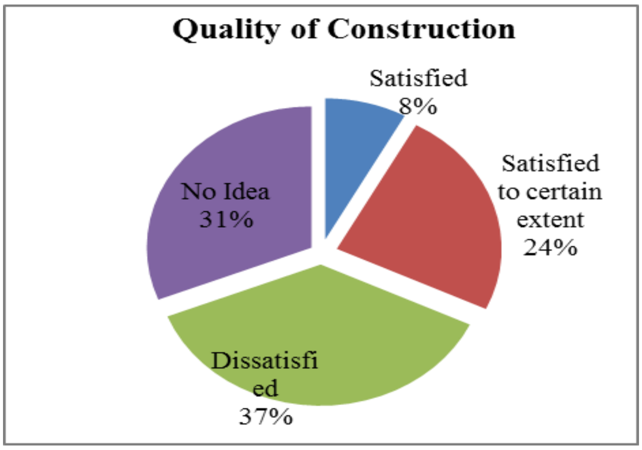

Figure 3: Quality of Construction

4.5. *LEGAL BACKGROUND*

This is another important characteristic considered during the survey. It was found that less awareness on the legal aspects in relation to the living in condominiums is another issue that exists with the low income families. Most of the occupants in these condominiums live without any concern about their responsibilities. According to the analysis, 43% of occupants said 'no idea' about the legal aspects and 25% claimed as dissatisfied. This proves the awareness of legal aspect is very poor among the community in the low income condominiums. However, majority of the problems associated with their living condition can be solved by providing proper awareness on legal aspects as well as their responsibilities in relation to living in condominiums as interdependency exist among the housing units and the inhabitants. During the survey it was found that majority of occupants do not have writing, reading skills and education level is at very low level. This is the reason that many occupants do not interest get to know about the legal aspects. However, people should pass this barricade in order to skip from common issues faced by them.

5. CONCLUSIONS AND RECOMMENDATIONS

The background to research shows that the demand for low income condominiums in the city of Colombo has gradually increased in the past few decades. This study was aimed to investigate the existing living condition of families in low-income condominiums in Sri Lanka in terms of their user satisfaction. The existing living condition of the occupants was identified under five significant areas namely, social condition, facilities availability, management and maintenance of facilities, design and construction, and legal aspects. The survey findings showed that 12% of occupants were satisfied with their social conditions. Most of these families do not have any fixed income. In terms of facilities available electricity, telecommunication and water received the highest level of satisfaction that is 67%, 62% and 57 % respectively. However, safety features of the electrical distribution systems, quality of water supply systems need to be improved. Only 23% of occupants were satisfied regarding the lighting and ventilation. Most of the low income condominiums does not comprise with systematic security system. Only 16% of occupants were satisfied with the accessibility. Merely 14% of occupants were satisfied with the acoustic quality and only 9% of occupants were satisfied with the availability of space in these condominiums. Furthermore, the respondents show their dissatisfaction on the areas of health and safety, sanitary facilities, waste disposal facilities, security and recreational facilities. Most of these issues of low income condominiums could be evaded through the implementation of proper design aspects. Moreover, the analysis showed that 43% of occupants were dissatisfied regarding the management and maintenance procedures and 37% of occupants were dissatisfied with the quality of construction. Proper procedures should be implemented in order to overcome these situations. Unawareness of legal aspects related to the living in condominiums among the users is another issue identified through the survey results.

It was identified that some of the available regulations have been neglected by the developers of low income condominiums when designing the condominiums. Thus it is pertinent to make centralised decisions in relation to allocation of land, adoption of standards, preparation of layouts, house plans and designs, infrastructure designs and installations, selection of materials, method of construction, finishes, planning, maintenance and management. In addition, it is worth to study user background, their behavior, attitudes, in order to provide acceptable living standards. Finally, it is recommended to carryout post occupancy evaluation surveys in regular basis in order to enhance the current living conditions and to provide stable and sustainable environment in the future condominium developments.

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MARKET FEASIBILITY AND PRACTICABILITY ASSESSMENT OF RUBBERISED BITUMEN FOR SRI LANKAN ROAD PAVEMENTS

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ABSTRACT

Conventional Bitumen (CB) has limitations in Sri Lankan context due to its tropical climate, as CB's low stiffness modulus, low softening point, low viscosity, high temperature susceptibility and poor cohesion properties are aggravated in this environment. This leads to cracks on the road surfaces, which subsequently leads to surface failure because of frequent heavy rains in the region. Therefore, to avoid the adverse properties of CB, the technical feasibility of modifying bitumen with natural rubber and crumb rubber has been studied recently. However, the question remains whether these options are economically feasible in the Sri Lankan context.

This paper presents a study which was carried out focusing the above issue. The study was carried out based on a preliminary literature review on the use of Natural Rubber Modified Bitumen (NRMB) and Crumb Rubber Modified Bitumen (CRMB) to identify technical feasibility and impacts, and an expert opinion survey with academic and industrial experts in the Highway field to identify the impacts.

These impacts were identified in three categories, i.e. Economic, Social and Environmental. Comparing the economic impacts and lifecycle cost aspects it was concluded that NRMB and CRMB are more economically feasible over CB. Moreover, during the study NRMB and CRMB were found to be more environmentally and socially feasible as well. CRMB further provides additional benefits as it uses recycled rubber, which in turn reduces environmental and social issues created by waste tyres. Furthermore, CRMB has a lower cost of modification compared to the NRMB. Owing to these aspects and the prevailing market situation, it was concluded that CRMB is more appropriate to Sri Lanka.

Keywords: *Conventional Bitumen; Crumb Rubber Modified Bitumen; Economical Feasibility; Natural Rubber Modified Bitumen.*

1. INTRODUCTION

An appropriate transportation system is of utmost importance to a healthy national economy, in which roadways are an integral part. Therefore, as Glover (2007) stated, construction and maintenance of long lasting road pavements will have a significant impact on the economic vitality of a nation. Further, according to Glover (2007), the main reasons for the deterioration of road conditions include the overall increase of traffic, poor quality of asphalt binder and weathering effects of climatic changes. Nevertheless, road pavement bitumen is thermoplastic, visco-elastic adhesives. In dense asphalt concrete, the binder is only about 5% but it plays very significant role in the overall properties of the composite material. The binder strongly affects both the load spreading capability and resistance to distortion under heavy traffic (Fernando, 2006).

The physical, mechanical, and rheological behaviour of bitumen in road and building construction is governed by its structure and chemical composition (Rahman, 2004). Asphalt can be classified by its chemical composition and physical properties. The pavement industry typically relies on physical properties of asphalt for the characterisation of performance, although the physical properties of bituminous binders are a direct result of its chemical composition (Glover, 2007). In fact, above information can be used to select, mix and/or modify asphalts to obtain binders that will perform in a cost-effective manner (Forbes *et al*., 2001). Currently there are various types of modifiers, capable of improving the performance of bitumen binders (Fernando, 2006). Fernando (2006) has discovered a modifier should have properties like; readily availability, improves some or most of the properties of bitumen, easily processed by conventional equipment, and cost effectiveness.

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Considering the rubber form of modifications for bitumen, there are highly available natural rubber (Form of latex or powder), Synthetic rubber, Vulcanized rubber (waste tires) and buffing dust from retreading tire industry to do the modification in Sri Lanka. According to the Bandini (2011) when crumb rubber is blended with bitumen at high temperatures (wet process) to produce a modified binder, the two materials interact once the bitumen components migrate into the rubber causing it to swell. Initially, the bitumen-rubber interaction is a non-chemical reaction, where the rubber particles are swollen by the absorption of the aromatic oils of bitumen. The impact of the CR modification improves the aging susceptibility, decreasing the binder aging ratio (Martinez *et al*., 2006). Moreover, NR is a fine organic polymer, because it is chemically very compatible with bitumen very effective and economical. The persistence elastic response of rubberised bitumen is primarily due to the entanglement of the flexible long chain rubber molecule together with some chemical reactions (Fernando, 2006).

In Sri Lankan context CB gain heavy economic losses due to a life of conventional road surfaces are minimised under hot climates and heavy axle loads and the cost of maintenance of the roads (Fernando, 2006). Thus, discovering the applicability and financial feasibility of Rubberised bitumen as an alternative modifier for CB for road construction in Sri Lanka is a timely requisite.

2. LITERATURE FINDINGS

2.1. PAVEMENT DISTRESSES AGAINST CONVENTIONAL BITUMEN IN SRI LANKAN ROAD PAVEMENT

Out of the approximately 30,000 km of paved roadways in Sri Lanka (RDA, 2007). Harischandra (2004), identified several types of road defects as the most visible defects in conventional bitumen penetration macadam roads, viz. road deformations, cracks, surface texture deficiencies, edge defects, potholes. The possible road deterioration causes for these defects were identified by the authors as; aging and weathering, environment (temperature, moisture), drainage and traffic.

Cracks are fissures resulting from partial or complete fractures of the pavement surface. According to Harischandra (2004), who illustrated reasons for cracks as; loss of waterproofing of pavement layers, loss of load spreading ability of the cracked material, pumping and loss of fines from the base course and loss of riding quality through loss of surfacing. In addition cracks of asphalt pavements are cracking that is associated with the development of thermal stress, usually manifesting itself as transverse and block cracking (Association of Asphalt Paving Technology, 2011).

Edge defects also have considerable importance in asphalt surfaces. These defects occur along the interface of a bituminous surface pavement and shoulder where the shoulder is unsealed (Western Bay of Plenty District Council, 2013). Furthermore, Harischandra (2004), illustrated edge defects frequently happen on one side of the roadway or tire wear and attrition.

2.2. INVOLVEMENT OF BITUMEN FOR ROAD DISTRESSES

Road pavement performance properties are mainly affected by the bitumen binder properties. It is well known that the rheological properties and durability of conventional bitumen are not sufficient to resist pavement distresses (Ali *et al*., 2013). According to Fernando (1998), who identified that properly designed roads with standard construction practices and good quality aggregate, most of the surface problems could be traced to the inadequacy of the quality of bitumen. According to the author, several road pavement distresses are directly related to bitumen properties. A list of road problems along with the associated properties of the binder is given in Table 1.

Table 1: Binder Properties in Road Problems

Road Distress Modes	Associative Properties of Binder
Rutting and Distortion	Low stiffness modulus, low viscosity, low softening point, high temperature susceptibility, poor cohesion.
Bleeding	Low stiffness modulus, low viscosity, low softening point, high temperature susceptibility.
Stripping	Poor adhesion, low resistance to water, poor cohesion.
Ravelling, Fretting	Poor cohesion, poor durability.
Brittle Fracture, Thermal Cracking	High stiffness modulus, higher temperature susceptibility, low ductility, low tensile strength, low flexibility, poor durability.

Source: Fernando (1998)

According to the Table 1, Fernando (1998) realised that to resist the road pavement from rutting and distortion binder properties with high stiffness modulus, high viscosity, high softening point, low temperature susceptibility and better cohesion required. Hence, most of the road problems could be minimized or virtually eliminated if a suitable modified binder to improve the above properties. However, conventional bitumen is unable to improve these properties any further (Ali *et al*., 2013).

2.3. MODIFIED BITUMEN

Asphalt modification using additives dates back to the last century (King *et al*., 1999). As well as the patents for using modified asphalt dates back to 1823 (Isacsson and Lu, 1995). The conventional bitumen have a range of theological and durability properties that are not sufficient for resistance on distresses caused by the increase in traffic and total loading on current roadways.

By specialised refining practices, chemical reaction, and/ or additives, it has been found out that conventional bitumen can be modified to improve the contribution of asphalt binders to the resistance of asphalt mixtures to various pavement distress (Lee and Kamyar, 2006). Furthermore, modified bitumen is formulated with additives to improve their service performance by changing such properties as their durability, resistance to ageing, elasticity and or plasticity (BP Bitumen Australia, 2013). Kim (2009) illustrated that a modifier can be selected to improve one or more of the main performance related properties of asphalt. Also different modifiers that affect different properties can be combined to improve several properties. Ideally, a modifier will change rheological properties to match requirements as defined by resistance to pavement distresses as shown in the Figure 1.

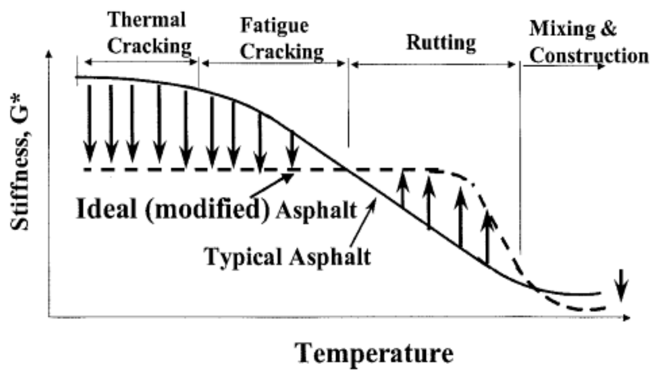

Figure 1: Schematics Shown the Target Change in Rheological and Failure Properties Expected
Source: Kim (2009)

Moreover, the Figure 1 can be used to realise that, several properties should be changed in bitumen modification to see an improvement in its performance (Fernando, 1998). They are; lower stiffness modulus at low service temperature to avoid thermal cracking, higher stiffness modulus at high service temperature to impact high thermal stability and hence to reduce rutting, permanent deformation and bleeding, lower stiffness modulus at compaction temperature and mixing temperature to improve workability at normal working temperatures, low temperature susceptibility, improved durability and cost effectiveness.

There are currently a large number of modifiers used for paving grade asphalts. From which, Kim (2009) showed that, Styrene Butadiene Styrene, Styrene Butadiene, Natural Rubber Latex and Crumb Rubber (Tire Rubber) are most commonly used in road industry.

Furthermore, most of the researchers believed that, the natural rubber and crumb rubber are adequate to use as modifiers for conventional bitumen. Hence the research finding is based on to find out the practicability side of these modifiers under Sri Lankan context.

3. Research Methodology

To achieve the study aims, qualitative comparative analysing approach was selected as the most suitable research approach. After the initial comprehensive literature survey undertaken to identify the technical feasibility of the natural rubber modified bitumen and crumb rubber modified bitumen, based on the data collected from industry and experts, the analysis was carried out to identify which modification is mostly suitable in the Sri Lankan context.

Semi-structured interviews were used in an expert opinion survey in this study to identify the market feasibility and practicability of bitumen modification with natural rubber and crumb rubber. Selected sampling was carried out to determine the interviewed experts, from industrialists, professionals and researchers in areas of natural rubber, crumb rubber, tyre and waste tyre. The initial interviews were carried out to determine the economic feasibility of deploying widespread use of natural rubber and crumb rubber asphalt. The following interviews were focused on the technical and practical implications it may have, and finally focusing on the marketability and environmental merits and demerits.

4. Research Findings

Roads and transportation systems are considered as the arteries of economic development in a country and presently, road construction is vastly increased in the past few years (RDA, 2007). Ergo, Sri Lankan Government proceeds lots of road construction projects (e.g. like highways, road ways) on various places in Sri Lanka. However, according to experts' opinion, Sri Lanka still has not done any modification in the bitumen mixture that is being used in these development measures. According to them, Sri Lanka is still heavily reliant on the conventional type of bitumen, which only lasts about 15 years.

The research findings, based on the experts' opinions are presented henceforth on three parameters which are highly impacted with bitumen modification with natural rubber and crumb rubber. The parameters are identified as economic, environmental and social factors, as illustrated in Figure 2.

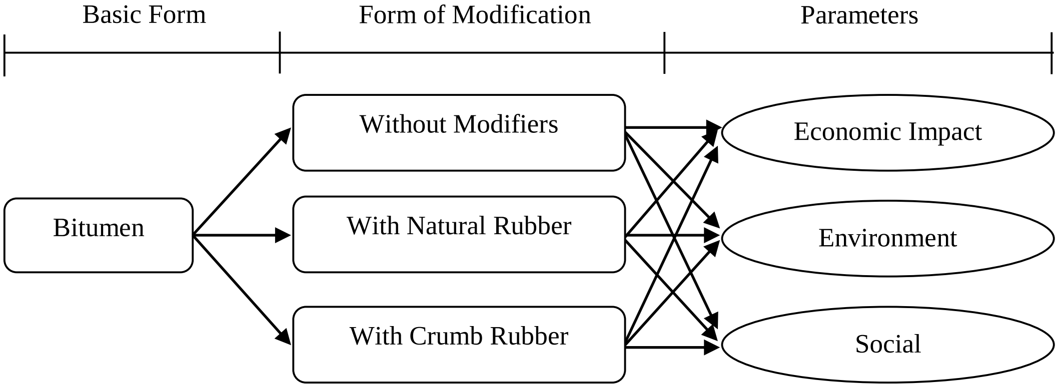

Figure 2: Form of Modifications and their Behaviours against Considered Parameters

4.1. ECONOMIC IMPACTS

The economic impacts suggested by the experts were based on the rationale that improvements to transportation networks, especially those in growing areas; tend to have impacts on local land markets. In principle, an improvement to a link in the network will confer economic benefits to adjacent and nearby properties. This study considered the initial cost of road construction (cost per km), cost of asphalt concrete (cost per km), cost of maintenance (cost per km) and life time of the design road separately for conventional bitumen pavement, natural rubber modified bitumen pavement and crumb rubber modified bitumen pavement. Table 2 shows a comparison between CB, NRMB and CRMB with relation to economic factors, as identified during the observations of the research.

Table 2: Economic Impacts

Parameter		Bitumen Modification		
		Conventional Bitumen	**NRMB**	**CRMB**
Economic	Cost of modification (Rs/Kg)	92.00	141.74	105.75
	Life span of the Road	15 - 20 Years	35 - 40 Years	35 - 40 Years
	Initial cost of Road Construction (LKR) per Km (X)	42,388,750.00	X > 42,388,750.00	X > 42,388,750.00
	Cost of asphalt concrete required to lay per Km (LKR) (Y)	14,093,750.00	Y > 14,093,750.00	Y > 14,093,750.00
	Cost of maintenance per month (Z)	250,000.00	Z < 250,000.00	Z < 250,000.00
	Government contribution for road construction	High amount of money have been allocated from the budget yearly for road rehabilitation and maintenance works	Comparatively less amount	Comparatively less amount

Results of the semi structured interviews showed that, bitumen modification with natural rubber and crumb rubber improves the service life and pavement performance also. Experts believe that, these modifications will increase the initial cost of roads and life span of a road. However, it was unanimously found that these modifications reduce the cost of maintenance of the pavements. The results of the market survey provided the required data to build a rate for each modification based on the cost needed to make 1 kg of modified bitumen. Hence, it is apparent that comparatively modified bitumen applications pose additional economic benefits over conventional bitumen apart from the increased initial cost.

4.2. ENVIRONMENT IMPACTS

Roads impact on the environment in many different ways, from the initial construction, maintenance, upgrading and usage of roads. Roads that impede drainage or cause run-off to be concentrated or polluted, can seriously degrade the environment. Furthermore, vehicles travelling on roads add to ambient noise and reduce air quality, which has the potential to affect people's health.

However, this study only discussed the environmental impacts due to road construction with CB, NRMB and CRMB pavements as established from the expert survey, i.e. reduction of natural resources, emission of gases, and noise intention to environment. Table 3 provides a summarised comparison of these environment impacts between CB, NRMB and CRMB.

Although, NRMB and CRMB provides additional impacts to the environment which are not mentioned in the Table 3, including, the possibility of increasing rubber cultivation in Sri Lanka. The study results showed that 15% of new constant demand for natural rubber will be added while establishing a NRMB production in the country, which will increase the current demand for rubber from estates. On the other hand, unusable tires are waste pilling up impacting the environment. The quantity of waste tire that is being trashed to the environment can be reduced by establishing CRMB production in Sri Lanka.

Table 3: Environment Impacts

Parameter		Bitumen Modification		
		Conventional Bitumen	**NRMB**	**CRMB**
Environment	Reduction of natural resources	Crude oil - 2,875,000.00 MT/Year Stone - 665,500.00 MT/Year	Comparatively less amount due to replacement of bituminous material	Comparatively less amount as virgin material is replaced by recycled material
	Emission of gases due to refinery and asphalt concrete manufacturing process	Accumulate high consistence of Sulphur Oxides, Carbon Monoxide, Vapours of Hydro carbons, Aldehydes and Ammonia.	Comparatively less amount	Comparatively less amount
	Level of noise intention during operational stage	60 - 70 dB	Approximately 30 - 40 dB	Approximately 30 - 40 dB

4.3. *SOCIAL IMPACTS*

Social impact are identified as significant potential positive and negative changes in peoples' cultural traditions and lifestyles, their physical and psychological health, their families, their institutions and their community. Out of the myriad of social impacts road construction poses, a handful was identified more prominent in this study based on expert opinions. Table 4 gives a comparison between these social factors as identified from the semi structured interviews.

Table 4: Social Impacts

Parameter		Bitumen Modification		
		Conventional Bitumen	**NRMB**	**CRMB**
Social	Unit cost to the vehicle operators	Unit cost to the vehicle (Rs/Km) Car- 5.3, two-wheeler - 1.33, truck - 12.14, bus - 11.32, LCV - 12.26.	Unit cost to the vehicle (Rs/Km) Car- 4.82, two-wheeler - 1.23, truck - 11.93, bus - 10.97, LCV - 12.07.	Currently under research
	Possibility of occurring road accidents	Having high possibility	Comparatively low possibility	Comparatively low possibility
	Travel time saving cost	Having considerable amount	Comparatively less amount	Comparatively less amount
	Level of disturbance people are facing while driving vehicle	Having considerable amount	Comparatively less amount	Comparatively less amount
	New demand for modifiers	-	8.05 Billion	1.38 Billion
	Benefits to the people	-	High demand for rubber states, labour salaries will increase	Waste tire converts to money and reduce hazards of dengue and air pollution

Table 4 shows that, the social impacts focused in this study were generally unit cost to the vehicle operator, possibility of road accident and travel time saving cost to people that has social impacts in CB, NRMB and CRMB road pavements. Additionally, productions of NRMB and CRMB provide more benefits to the society; i.e. having a big demand (Rs.8.05 billion) for natural rubber provide a protection to the rubber industry. When the industry is making profits, automatically these profits are distributed among the communities who are involved with the industry, which improves their quality of life. Moreover, CRMB production also provides opportunity to society to make money by selling unusable tire to the crumb rubber manufacturers. According to statistical data on waste tyres it makes Rs.1.38 billion from the sale of waste material.

5. CONCLUSIONS

The study focuses on the technical feasibility, economic, social and environmental impacts of Conventional Bitumen (CB), Natural Rubber Modified Bitumen (NRMB) and Crumb Rubber Modified Bitumen (CRMB). As per the literature section, it is apparent that all three bitumen types; CB, NRMB, and CRMB are technically feasible and provides reasonable performance in the pavement performance criteria in the Sri Lankan context.

The research findings were mainly aimed to discuss the impacts of various bitumen types. These impacts were identified mainly in three categories; Economic, Social and Environmental. Comparing the economic impacts, it can be concluded that NRMB and CRMB are more economically feasible over the CB. This is mainly due to the increase of life span decrease of maintenance of the pavement. NRMB and CRMB have a life span more than twice that of the CB. (CB has a life span of 15 year whereas other methods have a life span of 40 years.) This fact dominates over the increased initial cost of NRMB and CRMB about 10% - 12% of the CB.

However, overall life cycle cost of the pavement; has not been considered in this study due to the lack of information on this area in Sri Lankan context. These figures and a lifecycle cost data has to be taken into consideration by policy makers and development authorities to promote durable sustainable materials in our national development agendas.

The environmental impacts relating to these three methods are the mainly, loss of natural resources, emission during manufacturing process and construction of the pavement. Further it has considered the sound levels that are generated during the operational stage of the pavement. From the comparison of those facts it can be concluded that NRMB and CRMB is more environmentally feasible over the CB. This is mainly because of the less use of natural recourses and the reduction of sound level to 30-40 dB from 60-70 dB of CB.

Social impacts have been studied in terms of cost to the vehicle user, risk of accident occurring, disturbance during road maintenance, travel time saving due to the good condition of pavement. The study shows that both the NRMB and CRMB are better over the CB in this aspect also.

The conducted market survey revealed that the current market demand for NR is 70-75% of the production. This study has shown that the NR demand for modified bitumen rubber is less than 25% of the current production. Therefore, the demand can be satisfied without disturbing the current market as well as it will be a value addition to NR. Furthermore, CR will generate additional benefits as it is a recycling process, which would give answers to prevailing issues relating to rubber waste. Most importantly it will help reduce the environmental and social problems that are created due to waste tyres.

The market survey also revealed that, the production cost of modified bitumen is not severely dependent on the cost of rubber. Hence, the current market price for CR can be increased without much affecting cost of the final product. This will be an incentive to the public to interest them to motivate to recycle rubber; which will be an added advantage.

Therefore, it can be seen that using CRMB is more appropriate to Sri Lankan context. Although the market study has revealed that there is not enough CR in the local market they can easily be imported. However, the associated environmental, social and economic impacts of such strategy need to be further studies prior to any actual importation, owing to the fact that there is not enough research conducted on that area in the Sri Lankan context. Based on the market survey it was found that, price of CR will increase by 20-25% when importing for CRMB, even so, the impact of it will be not significant on the final output compared to total cost of NRMB. To end with, owing to the technical feasibility, economic, social and environmental impacts and especially due to the market situation, it can be concluded that Crumb Rubber Modified Bitumen is more appropriate to Sri Lankan road construction a as a modified bitumen.

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MEDIATION AS AN ALTERNATIVE DISPUTE RESOLUTION METHOD IN SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

Litigation is a traditional mode of dispute resolution; disadvantages of litigation have paved the way for the development of 'Alternative Dispute Resolution' (ADR) methods for settlement of construction disputes. Mediation can be identified as commonly practicing ADR method in international construction industry. However, the current experience of mediation method in the Sri Lankan construction industry is not that much popular with compared to the other ADR methods. Hence, it is essential to review the suitability of mediation method for resolving disputes in the Sri Lankan construction industry. Literature review was done together with the preliminary survey for the collection of information. Research problem was approached through interviews of experts in the construction dispute resolution. Findings of the research identified the mediation process, advantages, disadvantages, barriers for the implementation of mediation method and best ways of establishment by overcoming the barriers. Results of the research indicate the process, practice and establishment of construction mediation is suitable for the Sri Lankan context. Further, this research is limited to the evaluating the suitability of mediation only in resolving construction disputes in Sri Lanka. Data and information collection were limited to the experienced ADR practitioners who having analytical knowledge in mediation practice. It further revealed that the mediation method for the dispute resolution in the construction industry is suitable. The research further makes recommendations in order to make mediation method more effective and efficient in the Sri Lankan construction industry.

Keywords*: ADR Methods; Construction Industry; Dispute Resolution; Mediation.*

1. INTRODUCTION

Construction industry is a creator of a multitude of disputes due to its various inherent characteristics. Disputes have the potential to rise at any stage of the construction process. There is a growing trend across the globe to attempt resolving such disputes by Alternative Dispute Resolution (ADR) methods. Similarly, there is increasing involvement of construction professionals from engineering, architecture, quantity surveying and other disciplines in construction dispute resolution practice. The need therefore arises among other things to maintain greater consistency in the dispute resolution methods.

Alternative Dispute Resolution (ADR) is a general term encompassing various techniques for resolving disputes outside of courts of law using a neutral third party (Atlas *et al.,* 2000). There are varied means of ADR methods in used in the construction industry. There are four ADR methods: Negotiation, Mediation, Adjudication and Arbitration, commonly practicing ADR methods in the construction industry (Omar, 2007; Uff, 2005). Among them mediation method is rarely practicing in Sri Lankan construction industry (De Zilva, 2011). Mediation method has unique characteristics such as confidentiality, preservation of business relationship, cost and time saving, flexibility, voluntariness, generation of creative agreement, neutrality, fairness and higher levels of satisfaction (Yiu and Cheung, 2005) which could be directly or indirectly overcome drawbacks and conflicting spheres in other ADR methods.

2. MEDIATION METHOD AS AN ADR METHOD

Mediation is a structured and facilitated settlement method which involves a neutral professional facilitator called "mediator" who helps impartially and independently the parties to try to reach a settlement (Chau,

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2007; Frame and Reynolds, 2010). Mediator conducts the proceedings by taking particular account of the general circumstances of the case, the business relationship of the parties, parties' wishes and the need for a speedy and economical settlement.

3. MEDIATION PRACTICE IN SRI LANKA

There is no specified legislation which governs the construction mediation in Sri Lanka. Moreover, there is no any provision which focuses the disputant parties refer to mediation in a matter of construction disputes in the Standard Bidding Document (SBD) for conditions of contracts of Institute for Construction Training and Development (ICTAD). There is a provision that the disputant parties to be required to go for amicable settlement in conditions of contract of International Federation of Consulting Engineers (FIDIC) however FIDIC is not commonly used in local construction industry.

Even though mediation method is practiced for the settlement of commercial disputes in Sri Lanka. The Commercial Mediation Centre of Sri Lanka Act No. 44 of 2000 enacts to promote mediation and to resolve of commercial disputes. At present, concept of Mediation has been institutionalised through the Commercial Mediation Centre of Sri Lanka (CMCSL) and it is statutorily mandated to promote the wider acceptance of mediation for the resolution and settlement of commercial disputes. Also community mediation in Sri Lanka is based on the Mediation Boards Act No. 72 of 1988 and its recent amendments.

4. ADVANTAGES AND DISADVANTAGES OF MEDIATION METHOD

Chau, (1992); Brown and Marriott, (1999); Cheung, (1999); Kheng, (2003) have identified the effectiveness and reliability of mediation method by identifying advantages and disadvantages. The research is decided to represent the advantages and disadvantages of mediation method while comparing with the arbitration method as the basis. Those advantages and disadvantages are summarised in Table 1.

Table 1: Advantages and Disadvantages of Mediation Method

Advantages of Mediation	Disadvantages of Mediation
• Time effective	• No final and non-binding decision
• Cost effective	• Non enforceability of the decision
• Preservation of business relationship	• Less chance of honour outcome
• Protect privacy and confidentiality of the process	
• Flexibility in the process	
• Party autonomy	
• Non-involvement of lawyers	
• Expertise involvement	
• Non adversarial method and practice	

5. RESEARCH METHODOLOGY

Comprehensive literature survey was carried out based on journals, law texts, conference proceedings, government publications and previous research investigations. Due to the difficulties of gaining much awareness relating to the Sri Lankan construction industry, pilot survey was undertaken with the purpose of identify the level of mediation practice in Sri Lankan construction industry. Due to the limitations in existence of experienced ADR practitioners, who having an analytical knowledge in the construction mediation and other ADR methods, the number of expert interviews were limited to three. The framework of evaluating the suitability of mediation practicing in construction dispute resolution was developed through literature survey. Content analysis method was used to determine the presence of key concepts. Themes of findings in order to validate the literature findings and to identify the other findings which were necessary to further develop the frame work, within the data gathered through interviews. Cognitive mapping technique was used due to its suitability in displaying the relationships of views and concepts that identified from the research findings. Finally, according to the evaluation, recommendations were derived for the suitability and applicability of mediation as an ADR method in Sri Lankan construction industry.

6. LITERATURE REVIEW ON MEDIATION PROCESS

Gould *et al.* (2010) has revealed three main phases to mediation process and it was backed by Flake and Perin (2003) and Madden (2001). Those phases are, Pre mediation phase, the mediation phase and the post mediation phase. Therefore, it can discuss the mediation process under Said three phases.

6.1. PRE MEDIATION PHASE

Both the empirical findings and literature findings disclosed that, before the commencement of mediation, parties may submit and exchange the summaries of dispute between each parties and the mediator with the supporting documents in this stage. Further, literature findings disclosed some more activities which are done in this pre mediation stage. It was said that, a contract to mediate is used in this stage in order to agree the terms and the ground rules for the mediation where a mediation agreement includes details of items such as cost, confidentiality, without prejudice nature of the mediation, authority to settlement and time framework etc. Moreover, in this pre mediation stage, mediator will be also identified and parties may become to the mediation agreement.

6.2. MEDIATION PHASE

Gould *et al.* (2010) described this stage as heart of the mediation process. According to the literature findings, the mediator establishes the ground rules and motivates each party to make an opening statement during the first joint meeting. Once the parties have made their opening statements, the mediator may decide to discuss some issues in the joint meeting or in a private meeting called 'caucus' between the mediator and one of the parties. It was further stated that, the mediator will caucus with the parties in order to explore in confidence the issues in the dispute and options for settlement. The mediator may also use further joint meetings in order to narrow the issues and allow expert to meet the final settlement. Moreover, empirical findings revealed the purpose of having private meetings as to allow the mediator to gather the confidential information which is necessary to facilitate the mediation process to achieve a settlement from each party separately.

Further, literature findings revealed that the mediation phase is conducted on neutral territory rather than at the office of one of the parties to avoid the power imbalances. However, empirical findings revealed that the real mediation should be done within three separate rooms which served for each parties and the mediator. Further it was stated that at the beginning, all two parties and mediator may discuss about the matter together in joint a joint meeting. Then the mediator may conduct private meetings with each party separately in above mentioned separate rooms. And then again the joint meetings are conducted with the participation of all parties. However, this procedure is called as "Shuttle Diplomacy" as accordance with the empirical findings.

6.3. POST MEDIATION PHASE

As per the empirical findings, after the above mentioned procedure, parties may come to a settlement. Literature findings revealed that post mediation phase involves either executing the settlement agreement or if no agreement or only a partial agreement is reached, continuing with arbitration or litigation.

7. RESEARCH FINDINGS

7.1. SUITABILITY OF THE MEDIATION PROCESS

Suitability of mediation was evaluated in terms of mediation process, its practice and the establishment of mediation in the Sri Lankan construction industry.

According to the framework of evaluating the suitability of mediation as an ADR method in the Sri Lankan construction industry, suitability of the process was evaluated based on the advantages of the mediation process which are revealed by literature review.

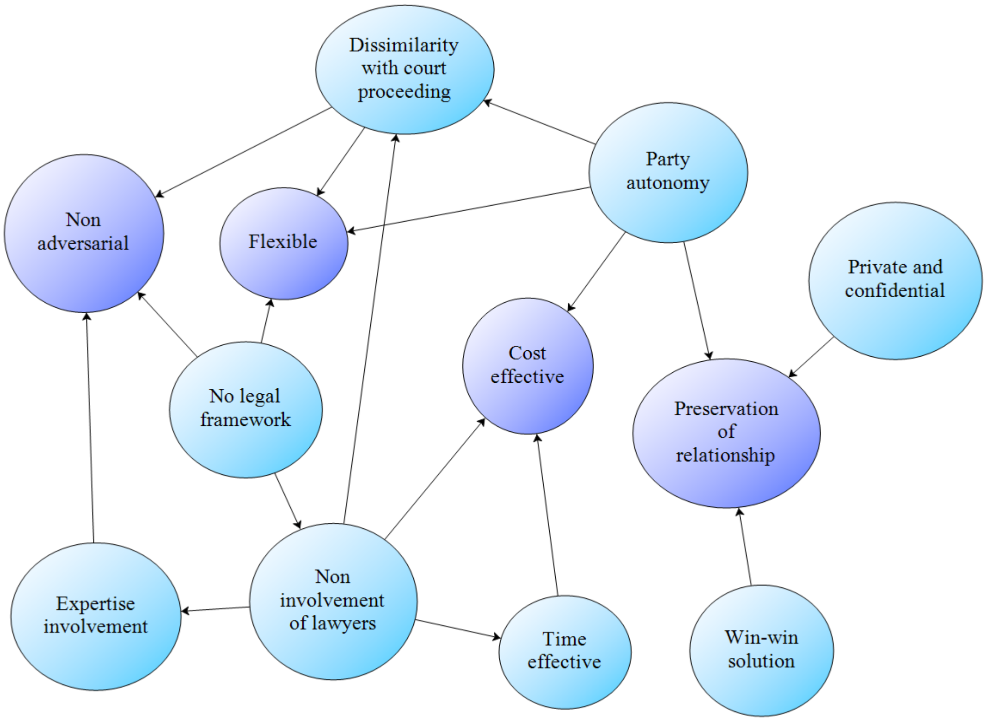

Figure 1: Cognitive Map of Advantages of Mediation

Above cognitive map (refer Figure 1), all the advantages of mediation process are presented with the additional key features of the mediation process as identified through the research findings. According to these relationships, it can be identified that preservation of relationships, cost effectiveness, non-adversarial and the flexibility are the key advantages of mediation process. As the main basis for creating several advantages of mediation, it can be identified as the party autonomy nature of mediation. Party autonomy directly leads to three key advantages: preservation of relationships, cost effectiveness and flexibility. Further, party autonomy indirectly leads to the other key advantage: non-adversarial as well. Hence, it can be apparent that the party autonomy is the most important feature of the mediation process.

As described by Madden (2001), an unnecessary long and expensive dispute resolution process will imperil existing business relationships and will add an unnecessary cost to carrying on business. Further, as per Cheung and Suen (1999), ADR methods are a collective term describing dispute resolution strategies which are having flexibility in the issues and non-adversarial approach not like in litigation. Hence, it is apparent that the cost, relationship, flexibility and the non-adversarial approach are the required characteristics through ADR methods in construction industry. Since, mediation gives all those characteristics as its advantages, this process is best suitable for resolving construction disputes in Sri Lanka, as required by the construction industry.

7.2. SUITABILITY OF THE MEDIATION PRACTICE

As per the framework of evaluating the suitability of mediation as an ADR method in Sri Lankan construction industry, suitability of the mediation practice was evaluated based on the disadvantages of the mediation and the suggested ways for the better practicing the mediation in order to minimise the disadvantages. Empirical data revealed that if the construction mediation is practiced in a proper way and if the parties are ready to accept the outcome of mediation, there won't be any shortcoming in mediation over arbitration practice.

According to cognitive map (refer Figure 2), it can be clearly identified that there are mainly three disadvantages in mediation and all these disadvantages lead to mediation to the failure. Furthermore, it can be identified that the main disadvantage of mediation is the not final and non-binding nature. This nature of not final and non-binding is the main reason of occur the other disadvantages of mediation. Therefore, it can be concluded that failing of mediation is the final outcome of the disadvantages of mediation and the main reason which lead to the mediation fail is the not final and non-binding nature of mediation. Hence, it is evidenced that the success of mediation should be achieved from the suggested ways of better practice of mediation. The main objective of those suggestions should be made the mediation final and binding in order to make mediation success. Hence it is necessary to analyse the suggestions for better practice of mediation, in order to evaluate the suitability of mediation practice.

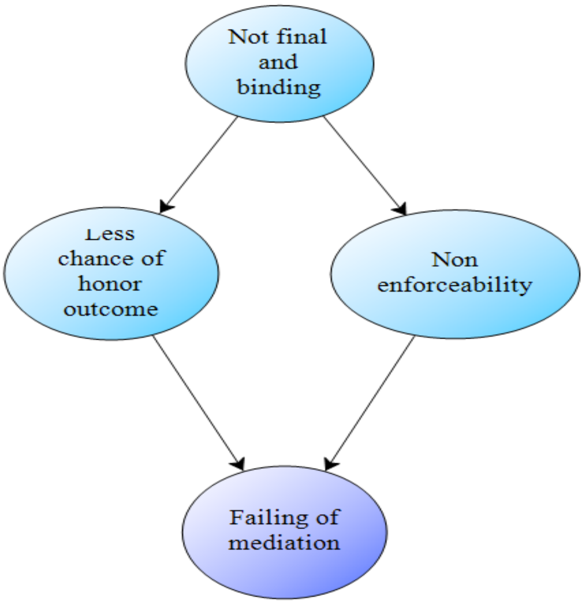

Figure 2: Cognitive Map of Disadvantages of Mediation

According to the above discussion on disadvantages of mediation practice, it was identified that the main disadvantage which leads to the other disadvantages of mediation is the not final and non-binding nature. Thereby this not final and non-binding nature is the main cause which leads the mediation fail which is identified as the final outcome of disadvantages. Hence, it is obvious that the Suggestions for better practice of mediation in order to minimise the disadvantages of mediation should mainly focus on the not final and non-binding nature of mediation.

As per cognitive map of Figure 3, it can be identified the main three suggestions lead to make the mediation final and binding. Then, the parties honour the outcome and thereby it minimises the failure of mediation as the final outcome of suggestions. Hence, it is evidenced that it highly overcomes the disadvantages of mediation practice through the suggested ways. Therefore, it is apparent that the practice of mediation is suitable in Sri Lankan construction industry.

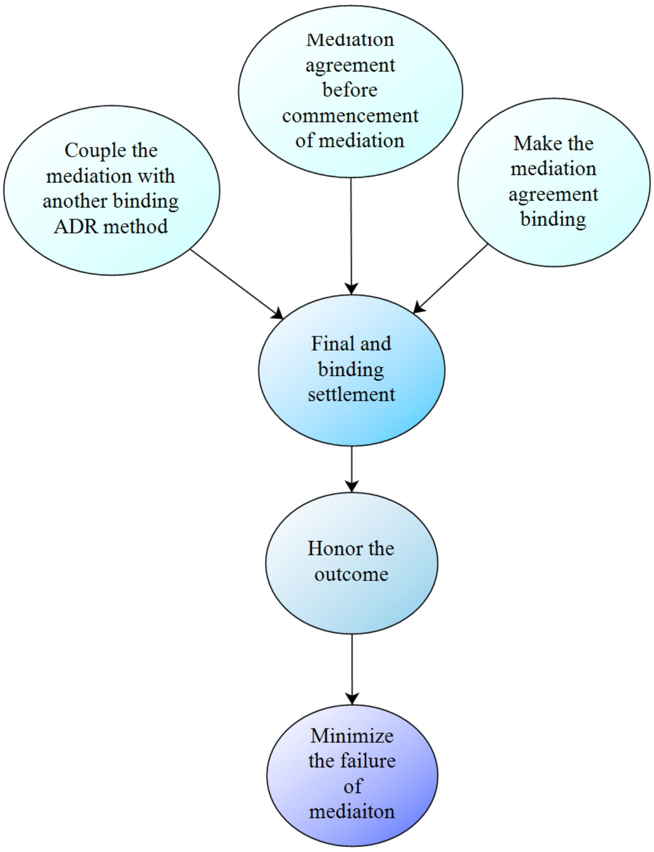

Figure 3: Cognitive Map of Suggestions to Overcome Disadvantages

Nevertheless, empirical findings specially stated that all the suggestions which have been stated to minimise the disadvantages of mediation practice should have to be established or practiced without changing the conceptual principal of mediation.

7.3. Suitability of the Establishment of Mediation

According to the framework, suitability of the establishment was evaluated based on the barriers for the establishment of mediation practice in Sri Lankan construction industry and the suggestions to overcome those barriers.

It can be identified that the main reasons for the barrier to widespread of mediation method are the disrepute of mediation, unawareness of method by stakeholders and general public and the absence of governing recognition for construction mediation in the Sri Lanka. Therefore, it can be identified that above barriers are as the key barriers for the establishment of mediation.

As illustrated by the map (refer Figure 4), lack of qualified mediators and the parties' mentality are the common reasons for the disrepute of mediation and failure of mediation. Moreover, unawareness of method leads to create the parties mentality in order to have a negative impact. Further, unawareness of method is the negative consequence of absence of prevailing law, lack of institutional framework and the non-practicing construction mediation in Sri Lanka. Moreover, absence of governing recognition is the negative consequences of absence of prevailing law and lack of institutional framework.

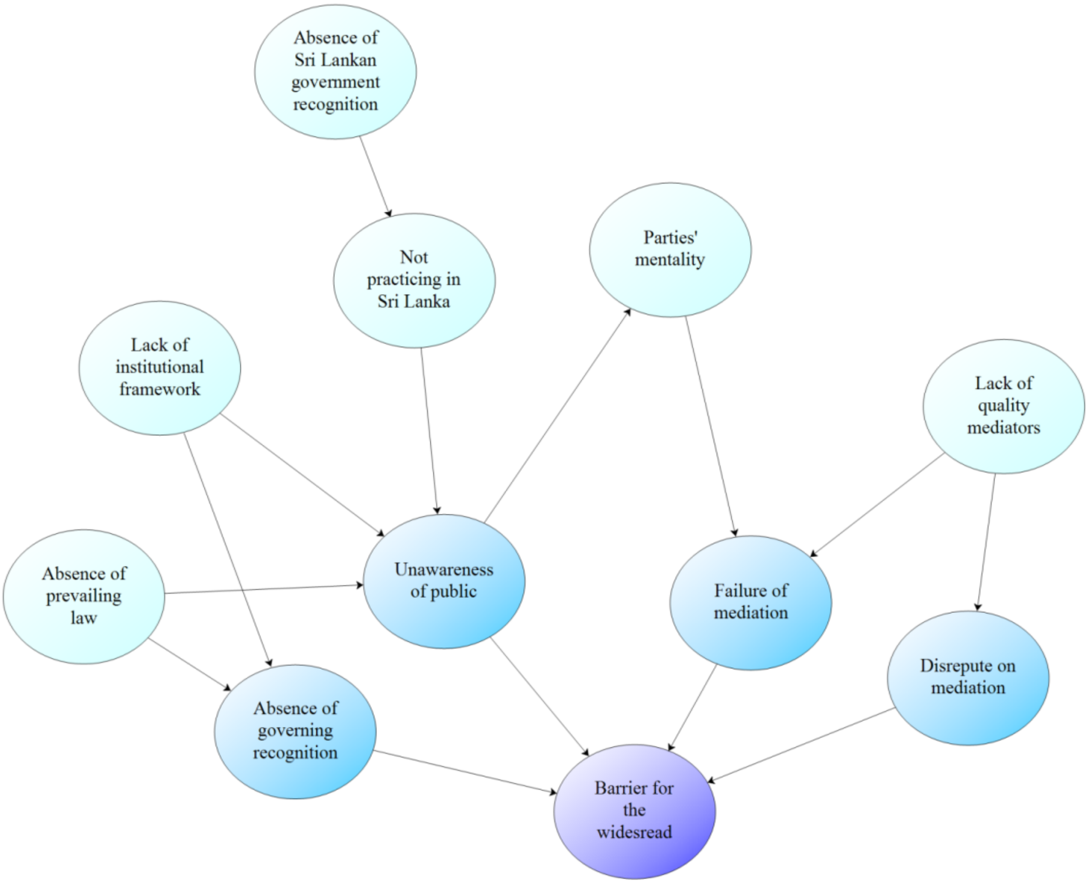

Figure 4: Cognitive Map of Barriers for the Establishment of Mediation Practice in Sri Lankan Construction Industry

Hence, it is obvious that through the suggestions, it should be created construction mediators who are suit as required in the mediation process and should be changed the parties' mentality. Further, background for the establishment of mediation should be well prepared in order to achieve a successful implementation with widespread.

According to the cognitive map (refer Figure 5), it can be identified there are four number of objectives are achieved through the suggested ways proposed in order to overcome the barriers. Those objectives are, increase the practice of construction mediation in the country, increase the awareness of mediation, establish a formal recognition and increase the skills and professional ethics of mediators. Thereby, it is expected to achieve the growth of mediation in Sri Lankan construction industry. Further, it can be identified that the development of the practice and the awareness are achieved through both the general public and the sources of establishments. Establishment of formal recognitions is expected to achieve through the sources. Finally, development of mediators' skills and professional ethics are expected to achieve through the development of mediators.

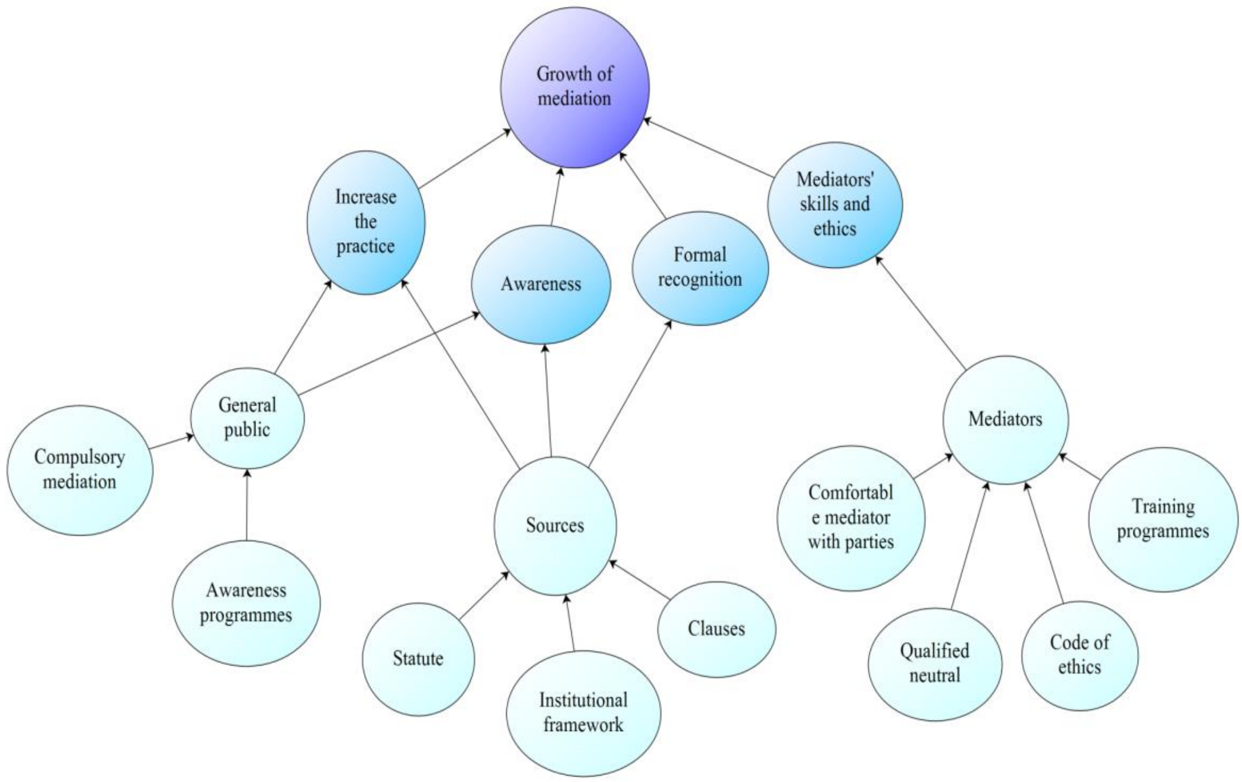

Figure 5: Cognitive Map of Suggestions to Overcome Barriers of the Establishment Mediation Practice in Sri Lankan Construction Industry

However, as identified in the cognitive map for barriers (refer Figure 4), main causes of barrier for the widespread of mediation are the skills of mediators, recognition by parties and formal recognition for the establishment. Hence, it can be concluded through this cognitive map (refer Figure 5) illustration for suggestions, all three main causes of barriers are concerned in order to increase the mediation practice, awareness, formal recognition and the skills and ethics of mediators. Hence, it can be said that the establishment of mediation practice also would be suitable. Nevertheless, the empirical findings revealed that through all these suggestions, the consensual nature of the mediation should be preserved and it should not be an imposed method and should not spoil the spirit of the mediation.

Finally general ideas of the interviewees' concerning qualities of mediation method can be stated as follows;

- Swift and fast decision making method
- Deliver impartial and decisive conclusions
- Cheaper and less costly method
- Less damage to the reputation and relationship of parties

The findings of this research indicate that the construction professionals have maximum level of satisfaction on the mediation practice. Therefore, much attention must be paid for the mediation method to settlement of disputes.

8. CONCLUSIONS

The ADR methods were introduced to minimise the drawbacks of litigation process. Mediation is rarely practicing ADR method in the Sri Lankan construction industry. Nevertheless, mediation has unique characteristics such as confidentiality, preservation of relationships, cost and time saving, flexibility, non-adversarial which could be directly or indirectly overcome drawbacks in other ADR methods. Suitability of mediation method was evaluated in terms of mediation process, its practice and the establishment of mediation in the Sri Lankan construction industry. Suitability of the process was proved through the key advantages of the mediation. Those key advantages are, cost effective, preservation of relationships, non-adversarial and flexible. Hence, the process of mediation is suitable to practice in resolving construction disputes in Sri Lankan construction industry.

Suitability of the mediation practice was proved from the disadvantages of mediation and the suggestions identified to overcome disadvantages when practicing in Sri Lanka. The main disadvantage which leads the decision is 'not final and non-binding'. The final outcome of the practicing of mediation in suggested ways is the 'minimise the failure of mediation'. Further the suggestions identified lead to make the mediation final and binding. Hence, when practicing the mediation as suggested ways, the practice of mediation is also suitable in resolving construction dispute in Sri Lankan construction industry.

Suitability of the establishment of mediation was proved from the identified barriers for the establishment of mediation practice in Sri Lanka. Four numbers of objectives are achieved through the suggested ways as, increase the mediation practice in the country, increase the awareness of mediation, establishing formal recognition and increase the skills and professional ethics of mediators. Therefore, the establishment of mediation is suitable in resolving construction dispute in Sri Lankan construction industry.

9. RECOMMENDATIONS

The followings are recommended to enhance the standard of mediation in the Sri Lankan construction industry.

- Require immediate review of existing standard conditions of contracts practiced in the construction industry and introduce construction mediation to the conditions of contracts.
- Implement proper construction mediation centres for small and medium level construction stakeholders.
- Maintain qualified panel of mediators by a regulating body of the construction industry.
- Construction mediation requires statutory recognition. Hence, there is a requirement of legislation which control and recognise construction mediation as an ADR method in Sri Lanka.
- Educational institutes have to experiment and take initiative to introduce mediation method and make the industry aware of the advantages of such method. Then there will be an incentive to industry professionals to adopt them into their practice. In addition they can organise CPD events which may allow experts to share their knowledge with others.
- Introduce speedy mediation method in order to minimise the time spent on the process.

Based on these evaluations it can be concluded that the construction mediation is suitable to practice for resolving disputes in Sri Lankan construction industry. Accordingly, the research found that though mediation has positive advantages over other ADR methods, however, it is not practice appropriately in the Sri Lankan construction industry. Therefore a further research can be done focussing on establishing a sound mediation practice in Sri Lankan construction industry.

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MERGING ACADEMIC RESEARCH AND CONSTRUCTION INDUSTRY DEVELOPMENT REQUIREMENTS: A CONCEPTUAL FRAMEWORK

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ABSTRACT

Academic research in built environment consists of cognitive and affective, as well as behavioural components. There is a broad consensus in the literature that successful communication between researchers and research users is crucial for the effective utilisation of research in decision-making in policy and practice. It is argued that academic researchers and the construction industry practitioners do not collaborate closely in construction sector. The need for sharing knowledge between research institutions and industry has become increasingly evident in recent years. Therefore this study aims to uncover the strategies in merging academic research with industry development requirements where this paper presents the literature review findings in a form of a conceptual framework. The importance of transfer, barriers for transfer and way forward for both academia and construction industry is presented within the framework with highlighted inter-relationships. The framework will be developed into a model after analysing findings of a field study which is to be conducted in the future with the use of Delphi technique. In that, the model will be validated with an expert survey where the panel includes both the academics and industry practitioners. Results of the study therefore are expected to serve both academia and industry in merging their interests towards the development of the sector.

Keywords: *Academic Research; Barriers: Construction Industry; Importance; Way Forward.*

1. INTRODUCTION

Construction industry needs to move beyond the traditional practices to adopt new practices arising from research and development (R&D) activities. Kulatunga *et al.* (2005) state R&D acts as a valuable input for the construction organisations. However, there is lack of evidence that construction industry adopts new findings of R&D activities into their practice (Pheng and Hua, 2002). In fact, partnerships amongst governments, economic sector and research universities are growing considerably, to make sure that new knowledge becomes linked to development goals (Kassel, 2009). However, relationships between academia and industry are increasingly intimate and commercial. While opportunities are created for each partner, there are also important conflict of interest issues (William *et al*., 2004). Academics are challenged when trying to implicate research into the practice, especially when they are demanded to involve in both pure and applied research while industry is challenged in moving away from the traditions and going ahead with current development trends. This urges the need of merging academic research and practice as the way forward. In merging research and practice, there would be subsequent requirements to be addressed with the preliminary requirement of developing relationships between researchers, funders and the practitioners. A collaboration where the interests and values of each partner are articulated in advance and conflict of interest issues are resolved before legal and business arrangements are established in a contract would be essential. Accordingly this study aims to explain how to merge academic research with industry development requirements to have a better responsive construction industry practice in Sri Lanka. The PhD research which this paper is based on has now reached its field survey stage where this paper presents the conceptual framework developed based on the findings of the comprehensive literature survey carried out.

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2. IMPORTANCE OF TRANSFERRING ACADEMIC RESEARCH OUTCOME TO THE INDUSTRY

Communicating research outcomes lies at the heart of academic endeavour, because it contributes to improved knowledge and understanding and guides further research. Moreover, bigger the project and the higher the level of the degree, the more likely it is that research outcomes would be worth communicating beyond the basic requirements to the broader research community. This may be beneficial to both the advancement of research in the particular field of interest and to the academic careers of the research graduates (Hays, 2007). Hence, the factors identified through the literature are presented in Table 1.

Table 1: Importance of Transferring Research Outcome – Academia's Perspective

Importance	References
Towards Academic Affiliation	
1. Research being a major responsibility, academics should carry out research that serves educational needs	Boyer Commission (1998)
2. To improve employment skills of the next generation of professionals	Fielden (2008); OECD (2010)
3. To attract new research students	Cullen, Joyce, Hassal, and Broadbent (2003)
4. To become a research-led university	Boyer Commission (1998)
5. Linking Research to improve Teaching	Boyer Commission (1998)
6. As communicating research outcomes lies at the heart of academic endeavour	Sparrow, Tarkowsky, Lancaster and Mooney (2009)
7. To guide further research	Sparrow, Tarkowsky, Lancaster and Mooney (2009)
8. To support individual professional development	Virolainen (2007)
9. For advancement of the academic careers of the research graduates	Hays (2007)
Beyond Academic Affiliation	
1. Research being a major responsibility academics should carry out research that serves the development of the region and its economy	Boyer Commission (1998); Virolainen (2007)
2. Add new knowledge in order to serve the wider society	Houston (2008)
3. To bringing in innovation to the particular industry	OECD (2010)
4. shaping the culture, paradigms and practices	Fielden (2008)
5. Accommodate and respond to key external parties in expectations	Houston (2008)
6. Dissemination of knowledge to the existing industry environment also becomes a duty to the academics	Boyer Commission (1998)
7. Source of new ideas and collaborating to maximising use of ideas	European Commission (2007)
8. For the advancement of research in a particular field of interest	Hays (2007)

Dissemination is only achievable and successful if, from the outset, there is a shared vision and common understanding of what one wants to disseminate together with a way of describing that to those who stand to benefit from it (Ordoñez and Serrat, 2009). Hence, it is essential to think about what benefits the knowledge product will offer to a particular industry.

Table 2: Importance of Transferring Research Outcome – Industry Perspective

Importance	References
At National Level	
1. Address the economic, environmental and resource constraints	Kulatunga, Amaratunga and Haigh (2005)
At Industry Level`	
1. To survive and proliferate through innovation	Hughes and O'Rourke (2009)
2. Develop new products, materials, advanced construction processes	Kulatunga *et al*. (2005)
3. Deliver better value for money	Fairclough (2002)
4. Increase construction industry productivity	Maqsood and Walker (2007)
5. Increased design and performance quality	Le and Bronn (2007)
6. Finding solutions to the challenges faced by the construction industry	Barrett (2007)
7. Making it highly valued by its customers	Barrett (2007)

Importance		References
At Organisational/Individual Level		
1.	In order to sustain long-term competitive advantage of organisations	Sparrow, Tarkowsky, Lancaster and Mooney (2009)
2.	Guide on effective management of human resources	Jones and Robinson (1997)
3.	‘Knowledge economy’ is an emergent reality for many organisations	Laszlo and Laszlo (2002)
4.	For continuous performance improvement	Hughes and O’Rourke (2009); Fairclough (2002)
5.	To become more profitable	Fairclough (2002)
6.	To be competitive through technological advances	Kulatunga, Amaratunga and Haigh (2009)
7.	Cost efficiency improvements	Le and Bronn (2007)
8.	Enhances the effectiveness of construction organisations	Kulatunga, Amaratunga and Haigh (2005)
9.	Managerial developments	Kulatunga, Amaratunga and Haigh (2005)
10.	Lead project team deliver high quality projects at lower costs in shorter times	Oyedele (2010)

3. BARRIERS FOR TRANSFERRING ACADEMIC RESEARCH OUTCOME TO THE INDUSTRY

According to Ordonez and Serrat (2009), where efforts to disseminate knowledge products are earnest, low impact is mainly attributable to poor planning and the absence of a dissemination strategy. Traditionally, it is found that the academic researchers and the construction industry practitioners do not collaborate closely in most construction research projects with creating lots of barriers for proper dissemination. The barriers for academics in transferring research which were identified through the literature review and are presented in the below Table 3 under the categories, internal barriers and external barriers.

Table 3: Reasons for Poor Research Interactions – Academia’s Perspective

Barriers		References
Internal Barriers		
1.	Demand to involve in both pure and applied research	William *et al.* (2004); Kassel (2009)
2.	Maintaining traditional role in public science while partnering with a commercial entity with a tradition of proprietary science	William *et al.* (2004)
3.	Increasing pressure from stakeholder groups in quality	Payne (1996)
4.	“Think global, act local” challenge	Kassel (2009)
5.	Poor planning and the absence of a proper dissemination strategy	Ordoñez andSerrat (2009)
6.	Low success in getting a share of research funds from abroad	Meek *et al.* (2009)
7.	Poor use of communication mechanisms	Pheng and Hua (2002)
External Barriers		
1.	Diminishing financial support from public sources of finance together with the high requirement of funds for developing activities	OECD (2010); Abbott, Aouad and Madubuko (2008)
2.	Passive and low dissemination	RD Direct (2009)
3.	Allocation of resources as R&D requires different type of resources	Senaratne *et al.* (2005);
4.	Changes in funding mechanisms	Senaratne *et al.* (2005)
5.	Fashionable management concept ignored by practitioners	Hambrick (1994)
6.	Changes brought by research will be seen over a long period of time rather than immediately at some points	Marsh (2010)
7.	Commercialisation threats to “open science” and academic freedom	Meek *et al.* (2009)
8.	Increased global competition in higher education and research	Meek *et al.* (2009)
9.	Indicators of “cutting-edge” research underscore gaps	Meek *et al.* (2009)
10.	Low- and middle- income countries have limited capacity for reviewing the quality of programmes	Meek *et al.* (2009)

Barriers	References
11. Resource pools for research in many low- and middle-income countries, even if financially sufficient, might be too small	Meek *et al.* (2009)
12. Goals of transnational education programmes and the paradigms of research so driven by the perspectives of economically advanced countries	Meek *et al.* (2009)
13. Practitioners often do not entertain innovative research ideas	Azhar (2007)

However significant evidence could be given from the industry to support the argument that the industry is slow in innovation adaption. At the same time, it is argued that the construction industry has considerable barriers to accepting innovation in general. Further these barriers can be again categorised into three as the barriers created at the national level, industry level and organisational or individual level. Therefore it suggests that the research outcome transfer is not totally the responsibility of academics but industry collaboration is essential backed with the national level action plans. Further the efforts will be rewarding for the national economy as construction industry being a major contributor to the national income in Sri Lanka.

Table 4: Reasons for Poor Research Interactions - Industry Perspective

Reasons	References
At National Level	
1. Moving away from the traditions and going ahead with development trends	William *et al.* (2004)
2. No necessary investments and benefit access to high-quality knowledge	Meek *et al.* (2009)
3. Lack of appropriate leadership	Jones and Saad (2003 cited Maqsood and Walker, 2007)
4. Timidity in leading the adaptation of new technologies	Jones and Saad (2003 cited Maqsood and Walker, 2007)
5. Ignorance about good quality academic research	Pheng and Hua (2002)
6. Not very influential and useful, especially when less-funded and consulted	BERR (2008)
At Industry Level	
1. Ignorance of the knowledge worker, their skills and skills agenda	O’Donnell (2008)
2. Pace of developments are integrated and implemented in the sector is slow	Hughes and O’Rourke (2009)
3. Low responsiveness to the changes	Bettelle (2010); Koebel, Papadakis, Hudson and Cavell (2004); Fiarclough, (2002)
4. Lack of investment on R&D by the industry	Bettelle (2010)
5. Culture of conservatism	Jones and Saad (2003 cited Maqsood and Walker, 2007)
6. Impractical to use in real- life construction projects	Azhar (2007)
7. Industry mind-set that academic research is not directly usable and valid	Pheng and Hua (2002)
8. Lacking direction and resources to test and implement research outcomes	Pheng and Hua (2002)
At Organisational/Individual Level	
1. Less adoption of new findings of R&D activities into practice	Pheng and Hua (2002)
2. Lack of skilled people in construction organisations	Kulatunga et al. (2005)
3. R&D expenditure as a proportion of turnover	Fairclough (2002)
4. Unawareness	Hughes and O’Rourke (2009)
5. Less knowledge	Hughes and O’Rourke (2009)
6. Competences among construction companies	Hughes and O’Rourke (2009)
7. Less incentives	Hughes and O’Rourke (2009)
8. Outdated skills of professionals	O’Donnell (2008)
9. Increasing costs to train employees in high technology environment	Wall and Ahmed (2008)
10. Academic research focused on subjects not crucial for industry	Azhar (2007)
11. Academic research results are sometimes inapplicable	Azhar (2007)
12. Poor learning organisational orientation	Jones and Saad (2003 cited Maqsood and Walker, 2007)
13. Lack of investment in people	Jones and Saad (2003 cited Maqsood and Walker, 2007)
14. More mature workers already active in the workforce	Hall and Sandelands (2009)

15.	Published in research journals that are difficult for practitioners to access	NCTM (2010)
16.	Reported in an academic style that makes them difficult to interpret	NCTM (2010)

4. Way Forward in Merging Academic Research and Industry Development Requirements

Based on the factors presented above, it could be argued that academic research and industry development should be merged so as to be more useful to practitioners and to policymakers, allowing the latter to make better-informed, less speculative decisions that will improve practice more reliably. In such a process of merging academic research and industry practice, several studies have identified many important elements which should be addressed. However, as Sabelli and Dede (2000) argue, the impetus for these changes must initially come from the research community. Therefore the research has identified some possible actions to be taken by the academia for proper research outcome dissemination. Further the actions were identified under three categories as to be considered at the initiation of the research, during the research process and finally at the dissemination stage.

Table 5: Way Forward for Academia

Way Forward		References
At the Initiation		
1.	Partnerships amongst governments, the economic sector and research universities to make new knowledge linked to development goals	Kassel (2009); Meek, Teichler and Keanrney (2009)
2.	Research to be more biased towards applied sciences over pure sciences	Virolainen (2007)
3.	Need to play a more active role in relationship with industry	European Commission (2007)
4.	Not only to overcome global challenges, but for individual industries	Marsh, (2010)
5.	Establishing networks of expertise on research	Abbott, Aouad and Madubuko (2008)
6.	Dissemination plan into initial academic research proposals	Ordoñez and Serrat (2009)
7.	Dissemination exercises with milestones identified and set early	Ordoñez and Serrat (2009)
8.	Research with structure and organisation, linked to the practical needs	EN (2011)
9.	Objectives; into supported activities, to respond to emerging policy needs	EN (2011)
During the Research Process		
1.	Quality researching	OECD (2010)
2.	Need to play a more active role in relationship with industry	European Commission (2007)
3.	Specialist staff to manage knowledge resources with business potential	European Commission (2007)
4.	Re-shape research culture with better compatibility with the industry	Virolainen (2007)
5.	Establishing networks of expertise on research	Abbott, Aouad andMadubuko (2008)
6.	Research with high dissemination capacity	Alker (2008)
7.	Balance teach-ability, complexity and specificity of research	Bogers (2011)
8.	Improve trust upon research findings	Bogers (2011)
9.	Include summary documents	Ordoñez and Serrat (2009)
10.	Letters of thanks to study participants	Ordoñez and Serrat (2009)
11.	Newsletters to study participants	Ordoñez and Serrat (2009)
12.	Quality control to ensure accuracy, relevant, representative, and timely	Ordoñez and Serrat (2009)
13.	Value creation process	Le and Bronn (2007)
14.	structure and organisation better linked to practical needs of the industry	EN (2011)
15.	Reduce complexities of research funding	EN (2011)
Outcome Dissemination		
1.	Specialist staff to manage knowledge resources with business potential	European Commission (2007)
2.	Higher the level of the degree, research outcomes worth communicating	Hays (2007)
3.	Establishing networks of expertise on research	Abbott, Aouad and Madubuko (2008)
4.	Availability of product to as large a proportion of the target audience	Ordoñez and Serrat (2009)
5.	Interactive dissemination process, allowing feedback from audiences	Alker (2008)

Way Forward	References
6. Active dissemination by tailoring research findings to a target audience	RD Direct (2009)
7. Packaging dissemination techniques	Meek (2009)
8. Shared vision and common understanding	Ordoñez and Serrat (2009)
9. Identify audience, map with awareness, understanding, action to be taken	Ordoñez and Serrat (2009)
10. Presented as a benefit and solution to users	Ordoñez and Serrat (2009)
11. Communicating to wider community beyond immediate research reports	Hays (2007)
12. Effective communication channels	Alker (2008)

This situation further dictates the need to enhance the academic researcher-practitioner collaboration for the construction industry (Azhar, 2007). Hence, this section further explores how such collaboration could be built in construction industry. According to the theoretical background findings there were some prominent actions which could be undertaken by the industry in order to create a better research integration into the practice. The actions were to be initiated as at the national level, industrial level or at the organisational or individual level. Further this aligns with the earlier findings of this research where it has identified barriers created at the national level and industrial level which requires higher level of action implementation.

Table 6: Way Forward for Industry

Way Forward	References
At National Level	
1. Develop open innovation approaches to R&D	European Commission, (2007)
2. Use public research as a strategic resource	European Commission, (2007)
3. Capacity building to access and use research	Alker, (2008)
4. Industry investments of self-interest or to respond to the demands	Koebel *et al*, (2004)
5. Development of procurement	Hall and Sandelands (2009)
At Industry Level	
1. Move beyond the traditional practices to adopt new practices	Kulatunga et al. (2005)
2. Research use included in job-descriptions	Alker (2008)
3. Skills agenda - the ability to attract, retain and develop skilled people is increasingly a required core competence	O'Donnell (2008); Hall and Sandelands (2009)
4. Updating knowledge of the workers comparatively with the new knowledge generation	O'Donnell (2008); Wall and Ahmed (2008); Amaratunga, Pathirage, Keraminiyage and Thayaparan (2010)
5. Development of strategic and professional leadership	Hall and Sandelands (2009)
At Organisational/Individual Level	
1. Combining in-house and external resources	European Commission, (2007)
2. Aim to maximize economic value from their intellectual property, even when it is not directly linked to their core business	European Commission, (2007)
3. Use as a criterion for staff appraisal	Alker, (2008)
4. Rewarding research-informed decision-making	Alker, (2008)

In merging research and industry development, it is crucial to have a strong link between these three related segments, researchers, practitioners and research funders. As Alker (2008) describes, communication between researchers, research funders and research users can happen in many different ways due to the number of different research users, the variety of research producers and the number of policy levels. Hence, there is a need to identify the ways and methods to link the addressed three sectors with effective communication channels where it leads for some collaborative actions. Therefore some actions that need can be implemented by academia and industry together were identified through the literature review are presented in the below Table 7.

Table 7: Way Forward for the Parties Together

Way Forward		References
1.	Collaboration where interests and values of each partner were articulated	Azhar (2007)
2.	Undergraduate research more into actual issues in the industry	Blackman and Kennedy (2009)
3.	Communication between researchers, research funders and research users	Alker (2008)
4.	Review how research be connected to real-world activity and policy setting	Marsh (2010)
5.	Research to be judged also by industry impact and tangible benefit	Marsh (2010)
6.	Joint publications between university, industry and government	Meek (2009)
7.	Knowledge broker	Alker, (2008)
8.	Embedding researchers within companies as part of existing research activity	Aouad, Ozorhon and Abbott (2010)
9.	Strategic partnerships	Meek (2009)
10.	Collaborations and partnerships among governments, economic sector and universities to make new knowledge linked to development goals	Meek (2009); Kassel (2009)
11.	Enhance researcher-practitioner collaboration to research on problems which are vital for construction industry and to find out adoptable solutions	Meek (2009); Azhar (2007)
12.	Broadening participation in programmes	EN (2011)
13.	Increasing the competitiveness and societal impact	EN (2011)
14.	Understanding the process and of building systems for innovation	Meek (2009)

Therefore a collaboration where the interests and values of each partner were articulated in advance and conflict of interest issues were resolved before legal and business arrangements were established in a contract is the correct path to head off.

5. CONCEPTUAL FRAMEWORK DEVELOPMENT

Conceptual framework was developed in order to present the literature survey findings in an easy to capture format as presented briefly in the Figure 01 given below. There have been identified two focused establishments as the ‘construction industry’ and the ‘academia’. ‘Academia’ is limited only to the scope of university academics who are researching into the area of ‘construction industry’. Major action focused under this research is the ‘knowledge transfer’ which is between the academia and the construction industry. Further three kinds of related links between the entities and the research knowledge transfer was uncovered within the clearance of theoretical background namely, the importance, barriers and way forward. ‘Importance’ was identified in two separate directions as the importance of research knowledge transfer from academia’s perspective and industry’s perspective. There were 19 factors to suggest the importance of transferring research knowledge from academia’s perspective, 26 factors to suggest that it is important from industry’s perspective.

Further, ‘Barriers’ were again identified in three way fold as reasons coming from academia reducing the knowledge transfer, reasons coming from industry and also reasons created by social influence. 25 reasons were identified from the literature as coming from the academia together with 50 reasons coming from industry perspective as for poor knowledge transfer.

Most importantly in achieving the research aim, the possible ways forward for each sector were identified. Further, there were some steps need to be taken by the two entities together. Actions to be taken by the disciplines were categorised under three stages as at the initiation during the research and at the stage of research knowledge dissemination. There were 16 possible actions were identified to be followed by the academics at the initiation of the research, 16 actions during the research process and thirteen actions to be followed at the outcome dissemination. Further, for the industry practitioners, there were 23 possible actions were identified. The actions were again divided into three groups as to be taken forward by national level, industry level and organisational/individual level. Further, some more 15 actions which can be implemented together by the industry and academia were identified to be tested in the industry through a properly designed field test which will be the next step of the original research which this paper is based on.

However, the paper presents only the latest factors due to the paper length restrictions.

6. SUMMARY AND WAY FORWARD

The construction industry being one of the important industries in the economy, it's stakeholders need to adapt complex and changing conditions continuously to sustain and proliferate through innovation. R&D acts as a valuable input for the construction organisations innovation in many ways. Therefore, it is important to move beyond the traditional practices in the construction industry to adopt research and development activities. This paper presents a framework developed based on the literature survey to promote better research outcome dissemination.

The main research study which this paper is based on aims to explain how to merge academic research and industry development requirements to have a better responsive construction industry practice in Sri Lanka. The objectives were set as below in order to achieve the research aim.

- Identify why research outcome does not disseminated to the industry from the point of the view of academics
- Explore the industry need for R&D
- Identify the reasons for industry's non–adoption of exiting academic research to fulfil the need from the point of the view of the practitioners
- Develop a mechanism to merge academic research and industry development requirements based on the results of first two objectives and by referring to models developed in other countries.
- Test the applicability of the developed mechanism in the actual setting.
- Develop guidelines to merge academic research with industry development requirements based on the testing experience.

A "mixed research method" conducted in Delphi rounds will be followed in achieving the research aim. As a research method, mixed method focuses on collecting, analysing, and mixing both quantitative and qualitative data in a single study or a series of studies. As Cresswell, (2006) explains, its central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than one approach alone. Surveys will form a part of the mixed method which will be followed here, which is discussed by Fowler (2008) as a method with the purpose to produce statistics, that is, quantitative or numerical descriptions about some aspects of the study population. According to Yin (1994), case study is an in-depth inquiry in its real setting that offers an explanation, exploration or description based on the case study actors, when the boundaries between the phenomenon and the context cannot be separated. Data which are to be collected based on this mixed method will be analysed scientifically. Conclusions will be to be made thereafter with the use of findings and a guideline will be developed to direct researchers and practitioners to create a better responsive construction industry for Sri Lanka.

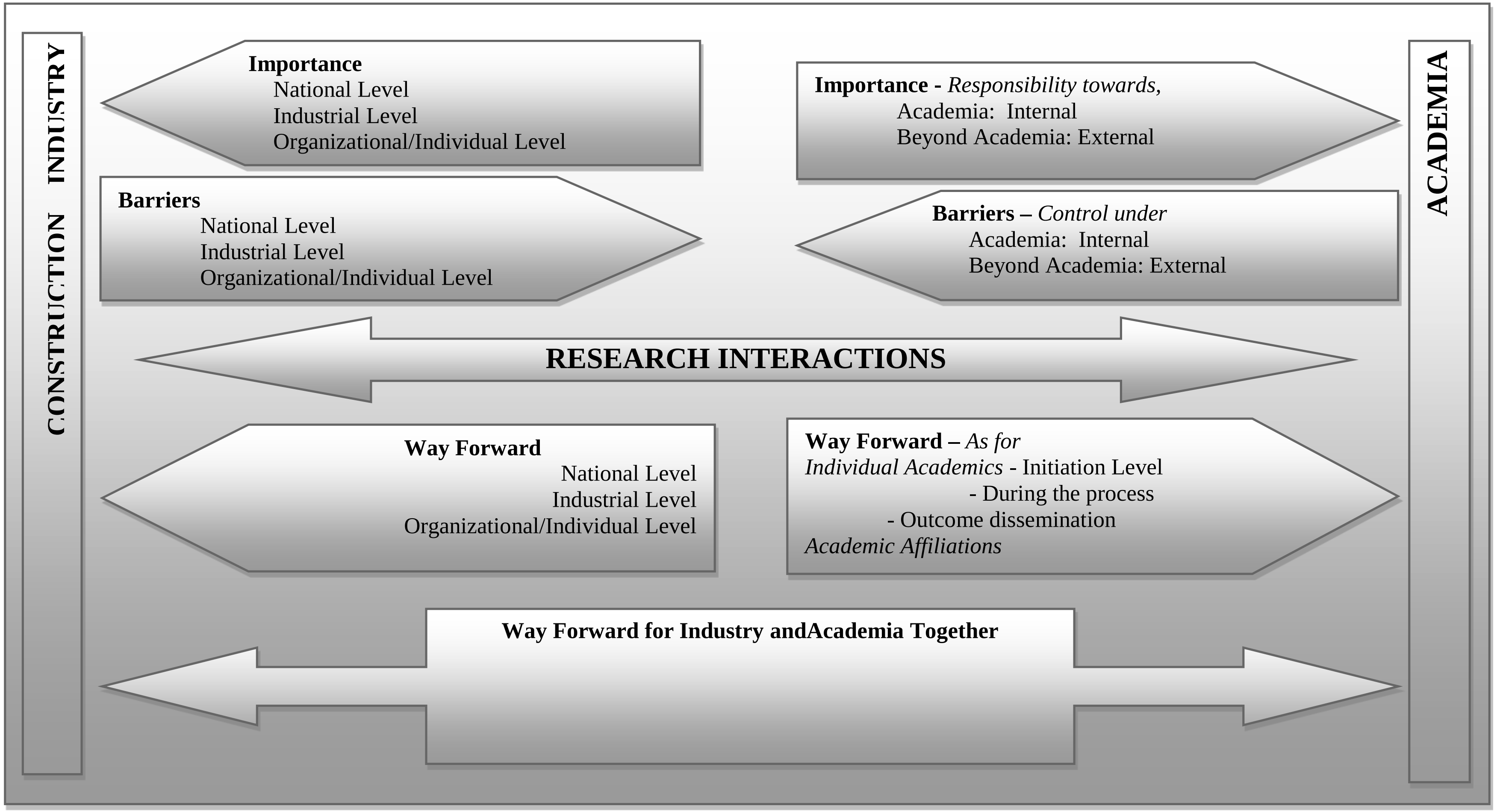

Figure 1: Conceptual Framework

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OPERATIONAL GAP ANALYSIS OF FIRE SAFETY APPLICATIONS IN SRI LANKAN HIGH-RISE BUILDINGS

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ABSTRACT

Life style confined with working and living in high-risers is a new concept to the Sri Lankan context. Scarcity of lands and urban development with the economic growth has accelerated the growth and popularity of tall and complex buildings in Sri Lanka. As such, in the conceivable future too, the progress of construction industry is likely to be dominated by high rise buildings. Fire safety is the most critical component within any type of building. High-rise buildings involve high-risk in fire emergencies due to the combination of three risk factors, which are high population density and various levels of mobility, design configuration of high-rise buildings, and excessive amounts of fuel load. The consequences of high-rise fires include the fatal and serious injuries to occupants, damage or loss of property and severe interruption to normal business activities. Hence, it is clear that significance attention on the fire safety is necessary to continue the operations of a building. Accordingly, this study aims to analyse the operational gaps in the fire safety applications in Sri Lankan high-rise buildings.

Case study method was selected as the most suitable research method for this study as it can be applied to explain presumed casual links in real life interventions. Furthermore, the primary source of data was collected through semi-structured interviews among professionals who involved with the fire safety management in Sri Lankan high-rise buildings. Data were analysed adopting content analysis. The research findings revealed that, in Sri Lankan context organisations were endeavouring within the bounds of possibility to fulfil the minimum requirements. Nevertheless, there is no considerable attention has given to achieve the acceptable standard for fire safety. Those differences were identified as operational fire safety gaps in high-rise buildings. Key reasons for the malpractices are inefficient fire safety systems, lack of knowledge and commitment of the management, design failures and lack of government's commitment. Therefore, organisations need to adopt a measured approach to minimise the gap and to achieve the acceptable standard.

Keywords: *Fire Safety; High-Rise Building; Operational Gap Analysis.*

1. INTRODUCTION

High-rise buildings have several characters and features that make them unique from other buildings (McGrail, 2007). ICTAD Fire Regulations (2006) defined high-rise building as "any building with more than ten floors including the ground floor, or whose height at any part of it above the ground level exceeds 30 meters excluding a lift or motor-room not exceeding 56 square meters". However, the existence of multiple occupied floors with the higher concentration of occupants creates comparatively a high potential for damages in case of a fire risk (Craighead, 2009). According to Pickard (1994), all buildings should incorporated with three broad fire safety objectives. At first is the Life Safety which requires adequate time and appropriate facilities to enable a safe escape. Secondly, Prevention of Conflagration which demands the prevention of fire spread from building to buildings. Thirdly, Property Protection which includes protection to contents such as furnishings fittings, objects of valve as well as the property itself. Moreover, safety system for a facility has to be designed in accordance with perspective regulations (Meacham, 1999).

During the last decade, the land values have risen up in Sri Lanka especially in Colombo and the high-rise culture became an inevitable reality that has to be faced by Sri Lankans (Aluthwala *et al*., 2007). Most of the Sri Lankan high-rise buildings do not pay considerable attention on fire safety applications which they deployed to prevent and control fire hazards (Aluthwala *et al*., 2007). Therefore, fire safety in high-rise buildings is a significant issue to be analysed in the Sri Lankan built environment.

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2. FIRE RISK AND SAFETY IN HIGH-RISE BUILDINGS

The fire risk in high-rise buildings has been special concerns to the fire community as long as there have been high-rise buildings (Ferguson and Janicak, 2005). The reasons being, natural forces affecting fire and smoke movement are more significant in high-rise buildings (National Fire Protection Association [NFPA], 1997). Furthermore, high-rise buildings affect the access of fire service personnel, fire apparatuses in reaching the upper floors of the exterior of the building. These unique features enhance the importance of fire safety in high-rise buildings. According to ICTAD Fire Regulations (2006), fire protection facilities are required to maintain by an organisation in a state of high operational efficiency at all times. Figure 1 shows some of the essential fire protection facilities.

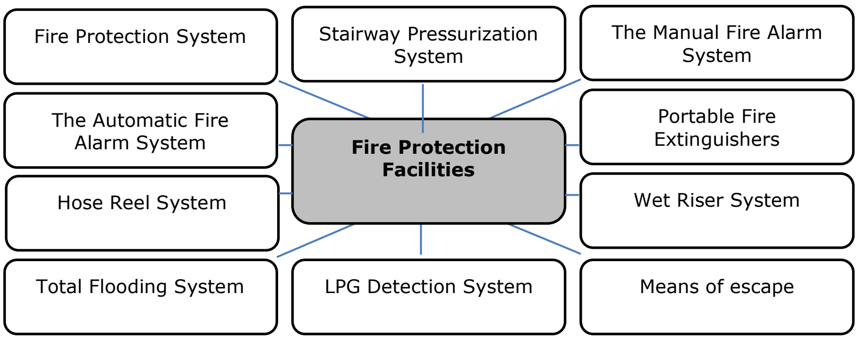

Figure 1: Essential Fire Protection Facilities
Source: ICTAD Fire Regulations (2006)

The fire protection measures are to curtail the danger to persons and property from fire. Two types of commonly used fire protection measures in high-rise buildings are active fire defence and passive fire defence (Daws, 1988). Active fire defences are devices or actions that must be receive a stimulus to act in a real or a perceived fire conditions (Fitzgerald, 2004). It includes fire detection systems and fire suppression systems such as smoke detectors, heat detectors, gas detectors, fire alarms, automatic sprinkler system, fire hose reels, stair pressurisation fire hydrants and fire extinguishers. As well as, passive fire safety defences defined as a building component that remains fixed in the building whether or not a fire emergency exists, it is the in-built feature of a fire precaution system which are fully available at all times in the building (Fitzgerald, 2004).

3. OPERATIONAL STANDARDS ON FIRE SAFETY

3.1. STRUCTURAL FIRE PRECAUTIONS

The purpose of structural fire precautions is to minimise the risk of spread of fire between adjoining buildings by a stable and durable form of construction, to prevent the untimely collapse of buildings in the event of fire and to prevent the spread of fire between specified parts of buildings by the division of such buildings into compartments (ICTAD Fire Regulations, 2006). Table 1 presents some of the structural fire precautionary requirements based on the ICTAD Fire Regulations (2006).

Table 1: Structural Fire Precautionary Requirements

Building Element	Requirement
Compartment wall / floor	Should be resistant to fire more than an hour
Staircases	Every staircase (including landing) which forms part of a building shall be constructed of non-combustible materials
Roof	All roof covering and roof construction shall be non-combustible

Source: ICTAD Fire Regulations (2006)

3.2. *FIRE EXTINGUISHING APPLIANCES*

A fire extinguisher is the basic fire protection device required to be in all type of buildings. SLS 831 (1988) defines, a portable fire extinguisher as a first aid firefighting appliance which can be carried by hand and the mess not exceeding 20 kg. Table 2 presents the classification of handheld extinguishers.

Table 2: Classification of Handheld Extinguishers

Standard	Type of Extinguisher	Definition	Capacity	Colour
SLS 815 (1988)	Water (stored pressure)	An extinguisher in which water is expelled by means of an inert gas or air, stored with, or dissolved in water under pressure	Not less than 9 litres	Red
SLS 704 (1985)	Water (gas cartridge)	An extinguisher which release on compressed gas from a cartridge to expel the water	Not less than 9 litres	Red
SLS 638 (1984)	Carbon dioxide	An extinguisher which expelled carbon dioxide as the extinguishing medium	Not less than 5 Kg	Black
SLS 785 (1987)	Powder	A portable fire extinguisher containing a powder as the extinguishing medium	Not less than 0.9 kg and not more than 14 kg	French Blue
SLS 831 (1988)	Foam (stored pressure)	An extinguisher in which foam is expelled by means of an inert gas, stored with or dissolved with in water under pressure	Not less than 9 litres	Pale Cream
SLS 724 (1985)	Foam (gas cartridge)	An extinguisher which release compressed gas from a cartridge to expel the form	Not less than 9 litres	Pale Cream

In addition at least one hydraulic hose reel need to be provided in every storey of a building and the hose reel should be of 19mm or 25mm diameter and not exceeding 45m in length (ICTAD Fire Regulations, 2006).

3.3. *FIRE DETECTION AND ALARM SYSTEM*

Every building or part of a building, shall be installed within a fire alarm system either automatic or manual type which shall be electrically supervised system. A fire alarm system of the automatic or manual type shall be provided with a fire indicator to indicate the location of the alarm which has been actuated or operated (ICTAD Fire Regulations, 2006). Further a manual alarm system shall be provided on every storeys of the building and shall be so located that no person need travel more than 30 m prom any position within the building in order to active the alarm (ICTAD Fire Regulations, 2006).

3.4. *FIRE LIFTS AND FIRE FIGHTING SHAFTS*

According to ICTAD Fire Regulations (2006), any building which floor level of any storey exceed 30m in height shall be provided at least one fire lift, which shall be contained within a separate protected shaft or a common protected shaft containing other lifts subject to such other lifts being served at each storey by the protected ventilated lobby. Figure 2 presents an illustration of a fire fighting shaft.

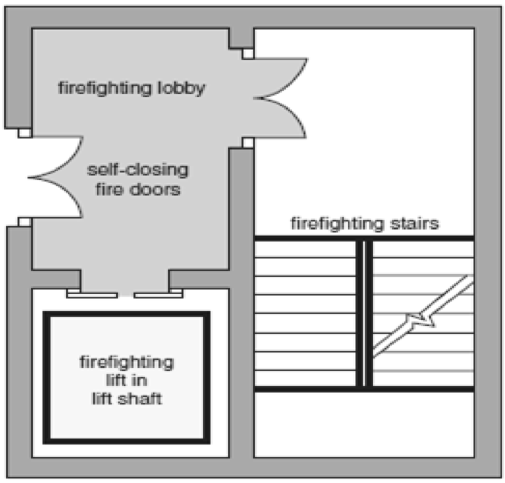

Figure 2: Fire Fighting Shaft
Source: Furness and Muckett (2007)

4. Current Status of Fire Safety in Building Environment

According to Fire Service Department statistics (2012), fire calls from office building are in a considerable level compared to hotels and warehouses. Major issue for occurrences of fires in office buildings is lack of applicability of current Sri Lankan regulations. On the other hand growth of fire hazards in Sri Lanka implies the poor planning for fire safety in buildings. Summary of fire calls received by fire service department is presented in Table 3.

Table 3: Statistical Data of Fire Calls

Building Category	2007	2008	2009	2010	2011	Total
Office Buildings	12	14	09	15	11	61
Warehouses	6	10	13	8	10	47
Hotels	4	4	5	6	7	26

Source: Fire Service Department (2012)

5. Research Method

Case study was selected as the most suitable research method for this study as it provides an in depth understanding about the meaning of the subject being studied not usually offered by other qualitative methodologies, and as having the ability to capture many variables with the aim of identify how a complex set of conditions come together to produce a particular manifestation (Hancock, 1998).

Furthermore, Yin (2009) found that, the use of the case study methodology is appropriate when organisational and managerial issues need to be examined.

This research study was carried out based on high-rise office buildings that have been deployed fire safety applications, each considered as a single case as the target group of data collection. Three high-rise buildings were selected in order to collect data for the empirical study. Profiles of the selected three cases are given in Table 4.

Table 4: Profile of the Cases

	Building A	Building B	Building C
Constructed Year	1996	1976	1992
Number of Floors	36	12	14
Number of Occupants	4280	1260	840
Building Category	Commercial	Government	Government
Person In-charge for Fire Safety	Facilities Manager	Premises Manager	Fire and Safety Manager

For this purpose semi-structured interviews were considered as ideal because it elicits more elaborative and purposeful answers from the respondents to the questions raised. Being so, the interviews were carried out among professionals in the respective industry and content analysis was conducted to analyse the interviews. The QSR.NVivo; version 7 was used to analyse the data. Table 5 presents the list of interviewees.

Table 5: List of Interviewees

High-Rise Building Professionals			Fire Brigade Professionals	
Facilities Managers	Premises Managers	Fire and Safety Managers	Fire Officers	Firefighters
2	2	1	2	1
Total - 5			Total - 3	

6. DATA ANALYSIS AND FINDINGS

6.1. OPERATIONAL GAPS IN FIRE SAFETY APPLICATIONS

Interview results illustrated that, although the fundamental fire protection and firefighting requirements are fulfilled in all the selected cases, the intrinsic value of the fire safety is not attained effectually. Fire safety gap is referred as the difference between the existing fire safety applications and fire regulation and/or fire safety standards in this study. Standards are emphasising only on installation of fire protection devices. Proper maintenance of fire safety equipment to ensure the quality of such devices is not in need of any witness according to the standards. Fire alarm system of Case B has not been tested for a long time and it is not in a working condition. This situation can lead the building to take long time to respond in case of a fire. Similarly, sprinkler system is not installed in Case C. Consequently, the occupants will be subjected to danger when fire growth is unattended. Therefore, not deploying an automatic alarm system and sprinkler system can be recognised as fire safety gaps of a high-rise building.

One of the fire officers of Colombo fire brigade asserted, *"A portable fire extinguisher is a first aid firefighting appliance. However, in most of the cases portable fire extinguishers are not carefully maintained by the building management. Moreover, they are hidden in the corners of the building"*. The statement of the fire officer revealed the ignorance of the building management on timely refilling and proper display of fire extinguishers. According to fire safety manager of Case C, the fire extinguishers of the particular building are not refilled due to budgetary issues. As a result, the building will lose the chances of immediate reduction of fire at an early stage.

According to the literature cited, if the floor level of any storeys exceeds 30m in height shall be provided at least one fire lift, which shall be contained within a separate protected shaft. However, two out of three selected high-rise buildings do not encompass a fire shaft. Furthermore, obstructed fire escape stair way was observed in Case B. These conditions will make the building more vulnerable in case of a fire. Based on the comments of a fire officer of Colombo fire brigade, a fire door should be resistant to fire for at least 30 minutes. However, fire doors were not installed in two of the selected cases. Moreover the exit sign boards are discoloured. These situations also can be recognised as fire safety gaps of high-rise buildings.

Standards on fire safety emphasises high-rise building to conduct fire drills since they accommodate a huge amount of occupants and the distance of evacuation is high. On the other hand, one of the selected buildings did not conduct a fire drill due to lack of trained staff and cost constrains. This may result in reducing the chances to identify weaknesses in emergency communications procedures and positive/negative reactions of staff with designated responsibilities.

Based on the above arguments it can be concluded that, operational fire safety gaps exist in the high-rise buildings of Sri Lanka even though the standards requires the optimum safety performance.

6.2. REASONS FOR MALPRACTICE

Organisations' performance on fire safety depends on several factors. A major cause for the gaps in the fire safety applications is malpractice of fire safety standards. The most common of the reasons for malpractice based on the responses are shown in Figure 3.

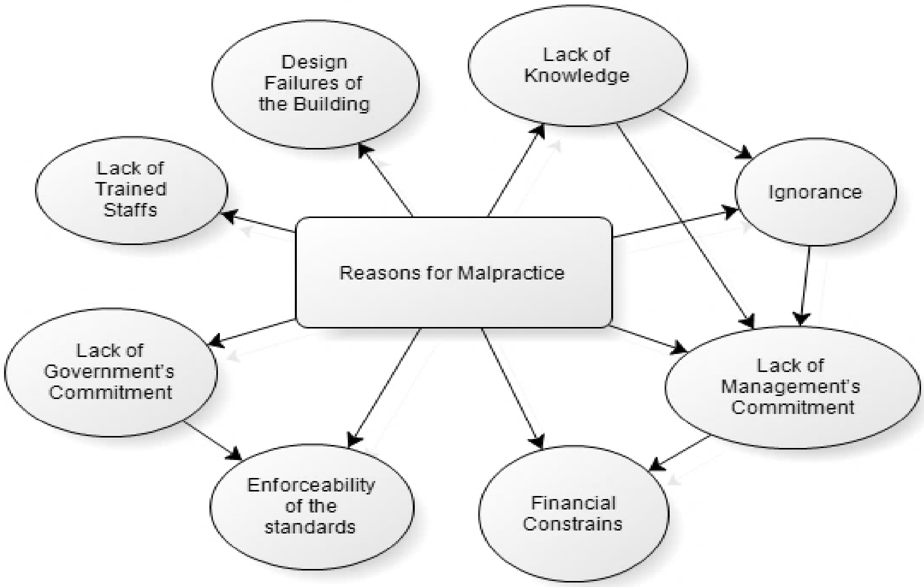

Figure 3: Reasons for Malpractice

Main reason pointed out by most of the interviewees is lack of management's commitment. Management's commitment depends on several factors including knowledge level, financial constraints and enforceability of the standards. As an assertion Fire and Safety manager of Case C mentioned "fire extinguishers of this building are not refilled due to budgetary issues". It shows the financial and other resource constraints of an organisation are one of the reasons for malpractice.

However, organisations are not solely responsible for malpractices by the reason of current standards do not require strict enforcement and continuous monitoring. However, organisations should improve their commitment towards fire safety in order to improve the performance of their building and to achieve their strategic objectives.

6.3. STRATEGIES TO MINIMISE OPERATIONAL GAPS IN FIRE SAFETY APPLICATIONS

In order to overcome from the identified gaps, building managers should adopt measured approaches. One of the fire officers of Colombo fire brigade stated that, *"organisations should give a special attention on available fire regulations to have all essential fire safety facilities to make the building safe".* Further he advice the managers of the buildings which are lacking with trained staff to appoint a third party as fire agents to install and maintain the fire protection system. As well as providing training to the existing staffs is equally important to monitor and coordinate the fire safety system. Another suggestion given by the fire safety officer of Case C is Fire Service Department and Urban Development Authority should take initiations to impose the standards on the buildings that are running with defective fire safety system.

According to the respondents, conducting a regular fire risk assessment with the assistance of Fire Service Department to identify fire safety gaps is another method which helps to develop the risk minimisation strategy. This will assist the organisation to identify the fire hazards, identify people at risk, valuate, remove or reduce the risks. Moreover, Facilities Manager of Case A suggested the high-rise building managers to maintain a fire plan and procedure manual to ensure the timely maintenance of firefighting equipment. One of the fire officers of the Colombo Fire Brigade stated that, *"if occupants do not given clear instructions they will automatically leave the building through the same route they have entered. Therefore the Public Addressing (PA) system should function in accordance with the intended evacuation strategy".* The statement reflects the importance of a good fire plan to a high-rise building.

Respondents further mentioned that, awareness of the building management have to be improved in order to adapt and maintain the required standards and to conduct fire drills. Because, the capabilities of the fire safety equipment will be assessed during the fire drills and it will enhance the communication with the Fire Services Department.

7. CONCLUSIONS

Based on the findings of the research study, various fire safety gaps were identified by means of comparisons based on compliance with fire regulations and relevant standards. According to the empirical findings, all the Sri Lankan high-rise buildings are not practicing all necessary fire safety procedures according to regulatory and standard provisions. Most common issues identified from the selected high-rise buildings are to lack of maintenance of means of escape, portable fire extinguishers, and directional fire safety signs and non-practicing of test evacuation drills. In order to avoid the losses that may result from a fire accident, organisations need to adopt a measured approach towards these gaps.

Based on the respondents' comments, several suggestions were presented to minimise fire safety gaps in high-rise office buildings. Improving the awareness level of building management and their commitment towards fire safety of the building, adapt emergency plans, take assistance of fire agents to rectify fire safety defects, and adhering to a proper maintenance system are some of the suggestions. A key suggestion for facilities managers is that they should recognise the importance of maintaining the fire related standards and should implement in their buildings.

This study was limited to fire safety applications in high-rise buildings in capital city of Sri Lanka. Case study samples were limited due to the scale of the study and the time constrains. Therefore this study can be continued to different types of buildings with a bigger set of sample. Furthermore, Facilities Managers' involvement on addressing these issues also can be studied through another research.

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PROJECT MANAGEMENT CHALLENGES IN IMPLEMENTING FOREIGN FUNDED WATER SUPPLY AND SANITATION PROJECTS IN SRI LANKA

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ABSTRACT

National Water Supply and Drainage Board (NWSDB) is the principal authority providing safe drinking water and facilitating the provision of sanitation to the nation. Therefore, it is the responsibility of the NWSDB to ensure that the projects undertaken be completed within the prescribed period of time and budget to the prescribe quality in order to assure quality water and an uninterrupted availability of water supply.

Most water supply and sanitation contracts do not meet set cost or time targets as a result of improper assessment of project management challenges. The majority of time and cost overruns are attributable to either unforeseen or foreseen project management challenges for which uncertainties were not properly accommodated. The normal practice is not to have proper review or retrospect at the end of the projects. However, the project management challenges still prevail in the industry as lessons learned but as tacit knowledge.

Identification of the project management challenges was done through a comprehensive literature review and a questionnaire was developed to assess the importance and the severity of the effect of each challenge. Relative importance of the challenges were identified analysing the collected data.

The key project management challenges in implementing foreign funded water supply and sanitation projects are related to human resources and should be addressed as a developing nation. National policies shall be introduced, modified, altered and diversified towards building skilled human resources, which is the demand of the future world.

Additionally, findings will provide an opportunity to both the NWSDB and the contractors to forecast possible critical scenarios and identify common pitfalls so as to eliminate the avoidable and highlight them to the management to avoid recurrences of such phenomena.

Keywords: *Human Resource; Project Management; Project Management Challenges; Water Supply and Sanitation.*

1. INTRODUCTION

Based on the present estimates, one sixth of human population lack access to any form of safe water supply within one kilometre from their homes. (Davison, *et al*., 2005) Women and their children are the ones who travel for miles every day to collect drinking water for their families. This task takes hours to complete which could be time they spend learning in schools or starting small businesses to help support their families.

Water demand has been on the rise all over the world. Population growth, rapid urbanisation, and overall expansion in economic activities are major causal factors underlying such increases in water consumption. The urban and regional demand for freshwater in Sri Lanka had grown significantly over the last decade (Hussain, *et al*., 2002).

National Water Supply and Drainage Board (NWSDB) being the principal water and sanitation facility supplying authority in Sri Lanka has a responsibility to supply water and sanitation facilities to meet the social aspiration of the people in terms of safety, reliability and effectively.

Economically, a water supply project in a community provides safe drinking water to women and children; giving them more time, freedom and incentive to help their families grow healthier and produce a productive members to the community. Socially, it is an indication of social status development of the

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particular community. Political interest in water supply is also not negligible. Finally the commodity that is being sold by the NWSDB is water. Since there's always a gap between the demand and the supply NWSDB focuses on timely completion of all the water supply projects.

However, there is enough evidence that the water supply and sanitation projects undertaken by NWSDB in the recent past have suffered heavily due to delays and cost overruns and as a result the public at large has suffered. Focusing on each project's challenges and learning from them will help to build a more capable and successful project management capability which avoids time and/or cost overruns and finally the nation benefits it by several means. The purpose of this study is to identify the project management challenges in implementing foreign funded water supply and sanitation projects in Sri Lanka. It is worth to study, analyse and understand the project management challenges, and thereby identify the probable modification to the existing practice to successfully implement water supply and sanitation projects in Sri Lanka.

Project management is a skill that takes time to develop in a person or in an organization. Construction Project Management is needed to look at the needs and risks, communicate the plans and priorities, anticipate problems, assess progress and trends, get quality and value for money and change the plans if needed to achieve objectives (Smith, 2002). A successful project owes all its credits to the Project Management and the evidence is obvious when the service (result of the project) meets all its expectations. Balancing all the elements of a complex project - time, money, scope and people - is the job of the Project Manager. Excellent project management training is essential to successfully dealing with the unexpected challenges that are unique and significant to the projects.

The discipline of project management is about providing the tools and techniques that enable the project team to organize work to meet time, cost and quality constraints in water supply and sanitation sector.

1.1. SCOPE AND LIMITATION

There are a few types of water supply and sanitation contracts in Sri Lanka. Foreign funded projects, local funded projects, community based projects, rural water projects and rain water harvesting projects are some of them. Since these different types of projects have particular project management challenges relate to each category, studying all the projects does not produce a reliable outcome. Hence, it was decided to focus on foreign funded contracts because they are the large scale projects having a massive impact on the sector. Further the major plants, where latest and challenging technology is applied, are the plants constructed with foreign funds.

The foreign funded projects are international and public – private combination projects which are the most challenging to manage. This is the speciality has led to choose foreign funded projects for the research.

2. LITERATURE REVIEW

Numerous studies on project management challenges were available in the literature on the project management sector. A wide variety of tools and techniques have been employed to evaluate project management challenges in these studies.

Most of the available past studies are those that deal with project management challenges in the context of developed economies, principally from the US. There are only a very few studies dealing with project management challenges in the developing economies. This important research area has largely been neglected in the past.

The study by Perera (2010), investigated the causes and effects of delays in construction of water supply projects with respect to the importance and the severity of the effects. Further, Premanath (1994) examined engineering management and time extension claims for NWSDB, using a questionnaire survey.

According to the previous researchers there are various adversarial relationships among the parties involved in the construction projects at the construction stage, where there are lot of uncertainties come into effect. Further as per their view there exist certain facts that may affect the cost, quality or duration of the projects. Those causes can be identified as the project management challenges that should be addressed by an effective project manager.

The project management challenges could be identified by referring arbitration proceedings, meeting minutes, letters, site log notes, variation orders, extension requests and various other documents maintained at site level. But considering the confidentiality of such records, lack of support from relevant authorities/officers and not maintaining the records for long period after the construction (most of the records are destroyed or misplaced once the construction period concludes) it was very difficult to gather data for this type of research from the site sources. Therefore, most of the researchers left with only one solution in extracting data using questionnaire survey with the participation of the professionals and the expertise in the project management field.

So far, no studies have been carried out on project management challenges in implementing foreign funded water supply and sanitation projects in Sri Lanka. The present study attempts to fill this gap by systematically analysing the project management challenges in implementing water supply and sanitation projects in Sri Lanka. The results of this study will enhance the understanding of the factors influencing the time and cost overrun and deficient quality, and certainly be useful future to project teams in water supply and sanitation sector and the government.

2.1. PROJECT MANAGEMENT CHALLENGES

Ford (2004) has identified unrealistic deadline, communication deficit, scope changes, resource competition, uncertain dependencies, failure to manage risk, insufficient team skills, lack of accountability, lack of engagement of customers and end-users during the project and unclear definition vision and goals as top ten project management challenges in construction projects.

Bee and Bee (2000) has identified that the people challenge plays a vital role in project management. They discussed the people challenge from the team forming for the project up to the winding up of the project. They believe that addressing and meeting the people challenge of project can make a significant difference in the industry.

The effect of people challenge in the industry is also highlighted by Bittner and Gregorc (2010). A team, a group, a project team or a community is not sustainable in the long term without the willingness practice, experience and learn together. Each individual must adapt and be able to fit into the team, but must also bring along his/her own strengths and show personal commitment in order to shape the group and keep it vibrant (Bittner and Gregorc, 2010).

Wirick (2009) revealed the challenges faced by the project managers in the field. He especially focused on the state sector project management challenges which were very useful for the study because the NWSDB itself is a government statutory board.

Engineering generally and the construction industry in developing countries are sufficiently different from those in the developed industrialised world. The range of types and size of construction companies is different, the environment in which they operate is different, the resources that are employed may be different, and the way projects are funded is different (Smith, 2002). In his studies Smith (2002) has highlighted the project management challenge in construction industry in developing countries. It should also be taken into account that there are particular challenges in managing projects in developing countries that are not recognised as challenges in developed countries like corruption.

The challenge in international project settings revolves around the fact that the projects are usually made up of multiple organisations, thus involving multiple organisational cultures involving several ethnic or country based culture. So the issues are actually cross cultural in nature and involve multiple issues (Dinsmore and Benitez, 2010). Dinsmore and Benitez (2010) listed out a set of project management challenges that should be addressed by a project manager who manages an international project.

Private sector project managers like to assume that their work is more demanding than projects in public sector. They assume that their projects are more complex, subject to tougher management oversight, and mandated to move at faster speeds. Although private sector projects can be tough, in many cases, it is easier to accomplish results in private sector than in the public sector (Wirick, 2009). In his findings Wirick (2009) has pointed out the public sector project management challenges.

2.2. CATEGORIES OF PROJECT MANAGEMENT CHALLENGES

The identified project management challenges were categorised into eight categories as follows;

- Design related project management challenges
- Administrative related project management challenges
- Organisational and organisational related project management challenges
- Resource related project management challenges
- Geological related project management challenges
- Communication related project management challenges
- Financial related project management challenges
- Other project management challenges (as safety, health, disputes, etc.)

These challenges effect time, cost and the quality of the construction which discourage all the parties contributing to the construction. Further the general public suffer the most with the interruption of potable water supply and at worst even having no access at all to the potable water supply.

3. METHODOLOGY

In attempting to analyse the project management challenges in foreign funded water supply and sanitation projects in Sri Lanka, this research employed an inductive quantitative research methodology through a combination of critical literature review and a process of questionnaire surveys.

The aim of the research was to analyse the project management challenges in implementing foreign funded water supply and sanitation projects in Sri Lanka. As the nature of the profession, the Project Managers in the construction field are really engaged with tight schedules. Therefore it was decided to use a well-structured, self-administrated type questionnaire and deliver it by hand, e-mails, and fax, which are the most reliable and the most economical and the rapid communication mediums available. The use of e-mail and fax helped to gather data from the respondents spread throughout the island and helped to increase the rate of response. Structured interviews that were based on the questionnaire were also used for collecting data from senior level Managers as they rarely respond to the questionnaire with their busy schedules.

The outcome of the literature reviews were filtered, since it is focused only on foreign funded water supply and sanitation projects. For the filtration, Delphi method was selected with a panel of expertise as the appropriate technique to finalise the research questionnaire for the survey. The success of Delphi method depends on the careful selection of the panel of expertise. Since the information solicited requires in-depth knowledge and sound experience about foreign funded water supply and sanitation projects, members for the panel of expertise were selected from among the senior management of NWSDB, who are expertise and professionals in water and sanitation sector construction. Real situation was addressed by appointing a panel of experts because they are the most qualified and the most experienced personnel in the industry who had gained wealth of experience by managing water supply and sanitation projects in Sri Lanka. All the twelve members of the panel of expertise have more than 20 years of experience as professional managers in water supply and sanitation sector.

The questionnaire was developed to assess both the importance of these project management challenges and their effects to the projects, from the view point of clients and contractors.

3.1. SAMPLE SELECTION

Stratified sampling technique was used as the data analysed based on the designation of the company of the respondents (Project Managers). The population was sub-sampled and these sub samples collectively presented the total sample. The participants were professional managers who were/are engaged in foreign funded water supply and sanitation projects in Sri Lanka. Professional qualification and the experience in water supply and sanitation projects of the participants discussed in Data Analysis.

There were 46 respondents from the client/consultant category while there was 33 from the contractor category and the total sample consisted with 79 respondents.

3.2. DATA ANALYSIS METHODOLOGY

The ranking of the project management challenges in implementing foreign funded water supply and sanitation projects in Sri Lanka from the viewpoint of the client/consultant and contractor was done using the three indices frequency index (FI), severity index (SI) and the relative importance index (RII).

4. DATA ANALYSIS

Considering the qualification of the sample selected, 100% of the sample's client professionals had BSc or higher educational qualification and 70% of the sample's contractor professionals had BSc or higher educational qualifications. As a whole 87% of the sample bear BSc or higher educational qualification. Further 100% of client professionals, 64% contractor professional and 85% of the total sample bear more than five years of experience in water supply and sanitation sector.

The responses to the questionnaire were analysed from the clients', contractors' and overall perspectives based on frequency of occurrence and the severity of the effect to the project. The score for each project management challenge was calculated by summing up scores assigned to them by the respondents and then the three indices related to frequency of occurrence, severity of the effect to the project and the importance were calculated using the three ranking indices stated under methodology.

4.1. DISCUSSION OF RESULTS

First, the results obtained by analysing the project management challenges in implementing foreign funded water supply and sanitation projects in Sri Lanka were discussed and compared the client, the contractor and overall perspective. Then the results obtained by the analysing the severity of the effect to the project due to the identified project management challenges were discussed. The importance of the fifty identified project management challenges in implementing foreign funded water supply and sanitation projects in Sri Lanka depended on both the frequency of occurrence of particular challenge and the severity of its effect to the project.

4.2. FREQUENT PROJECT MANAGEMENT CHALLENGES

The Frequency of occurrence of a project management challenge is a significant aspect, which used to determine the importance of the particular project management challenge. The client ranked inefficient and improper planning and scheduling by the contractor (with FI 66.5%) as the most frequent project management challenge in implementing foreign funded water supply and sanitation projects in Sri Lanka while the contractor highlighted shortage of skilled resources (with FI 66.1%). Furthermore as a big picture shortage of skilled resources (with FI 66.1%) could be identified as the overall frequent project management challenge in implementing foreign funded water supply and sanitation projects in Sri Lanka. This supported the finding of Haughey (2009) at the perspective of client. The project teams should focus on efficient, proper and realistic project planning of the projects.

The contractor's and overall view of most frequent project management challenges complied with the world trend of scarcity of skilled manpower. This was shown by the reports by Wang (2010), and Hanim (2010). Wang (2010) postulated that the global economic crisis is another reason for the occurrence of labour shortages. Sweis *et al*. (2008) also indicated that shortage of manpower including skilled, semi-skilled and unskilled labour causes delays in construction projects. This is further supported by Sambasivan and Soon (2007) who conducted a study in Malaysia and found out that labour supply is ranked number seven out of twenty eight causes of construction delay.

Table 1: Most Frequent Project Management Challenges

Client Perspective	Contractor Perspective	Overall Perspective
Inefficient and improper planning and scheduling	Shortage of skilled resources	Shortage of skilled resources
Political influence	Lack of motivation for human resources	Employee turnover
Shortage of skilled resources	Shortage of staff with required qualification	Shortage of labour power
Shortage of labour power	Employee turnover	Lack of motivation for human resources
Employee turnover	Shortage of staff with required experience	Political influence
Financial difficulties of the contractor	Shortage of labour power	Equipment breakdown
Delays in commissioning other related projects	Equipment breakdown	Shortage of staff with required qualification
Poor communication and coordination among parties	Organisation’s rules which delay decision/control	Shortage of staff with required experience
Equipment breakdown	Financial difficulties of the contractor	Inefficient and improper planning and scheduling
Lack of motivation for human resources	Cash flow problems	Financial difficulties of the contractor

4.3. SEVERE PROJECT MANAGEMENT CHALLENGES

The results of the analysis showed that the clients’ ranked ineffective and improper planning and scheduling by the contractor (SI = 66.1%), shortage of skilled resources (SI = 55.7%), shortage of labour power (SI = 54.8%), political influence (SI = 53.5%), employee turnover (SI = 51.3%) as the top five project management challenges which could cause severe effect to the foreign funded water supply and sanitation projects in Sri Lanka. Shortage of skilled labour resource (SI = 67.9%), shortage of staff with required experience and qualification (SI of 63.0% each), shortage of labour power (SI = 59.4%) and employee turnover (SI = 57.0%) has identified as the challenges which had severe effects to the project by the contractor. In overall view, shortage of skilled resources (SI = 60.8%), shortage of labour power (SI = 56.7%), employee turnover (SI = 53.7%), shortage of staff with required experience (SI = 50.1%) and ineffective and improper planning and scheduling (SI = 49.6%) caused the severe effects to the projects. In the overall analysis, four out of top five severe project management challenges were human resource related project management challenges. However, this finding tallied with the finding of Saleh (2010).

Table 2: Most Severe Project Management Challenges

Client Perspective	Contractor Perspective	Overall Perspective
Inefficient and improper planning and scheduling	Shortage of skilled resources	Shortage of skilled resources
Shortage of skilled resources	Shortage of staff with required experience	Shortage of labour power
Shortage of staff with required qualification	Shortage of staff with required qualification	Employee turnover
Political influence	Shortage of labour power	Shortage of staff with required experience

Client Perspective	Contractor Perspective	Overall Perspective
Employee turnover	Employee turnover	Inefficient and improper planning and scheduling
Financial difficulties of the contractor	Equipment breakdown	Shortage of staff with required qualification
Poor communication and coordination among parties	Financial difficulties of the contractor	Financial difficulties of the contractor
Equipment breakdown	Organisation's rules which delays decision/control	Equipment breakdown
Lack of motivation for human resources	Cash flow problems	Political influence
Shortage of staff with required experience	Geographical distribution of the project	Poor communication and coordination among parties

4.4. *IMPORTANT PROJECT MANAGEMENT CHALLENGES*

The results of analysis showed that there were several important project management challenges that should be identified in implementing foreign funded water supply projects in Sri Lanka.

Table 3: Most Important Project Management Challenges

Client Perspective	Contractor Perspective	Overall Perspective
Inefficient and improper planning and scheduling	Shortage of skilled resources	Shortage of skilled resources
Political influence	Shortage of staff with required qualification	Shortage of labour power
Shortage of skilled resources	Shortage of staff with required experience	Employee turnover
Shortage of labour power	Shortage of labour power	Shortage of staff with required experience
Employee turnover	Employee turnover	Shortage of staff with required qualification
Financial difficulties of the contractor	Equipment breakdown	Inefficient and improper planning and scheduling
Poor communication and coordination among parties	Lack of motivation for human resources	Political influence
Equipment breakdown	Financial difficulties of the contractor	Equipment breakdown
Lack of motivation for human resources	Organisation's rules which delays decision/control	Financial difficulties of the contractor
Delays in commissioning other related projects	Cash flow problems	Lack of motivation for human resources

The degree of agreement between the two parties regarding the importance of the project management challenges was tested using spearman's rank correlation coefficient. Low value of 0.59 of rank correlation coefficient indicated low agreement between the parties.

5. CONCLUSIONS

The key project management challenges in implementing foreign funded water supply and sanitation projects were related to human resource. Shortage of skilled and unskilled labour force, shortage of technical staff with required experience and qualification, employee turnover and lack of motivation for human resource were among them. Political influence was also another factor. Equipment breakdown, inefficient and improper planning and scheduling, financial difficulties of the contractor were also top project management challenges in implementing foreign funded water supply and sanitation projects in Sri Lanka.

Human resource challenge will be the critical challenge we have to face as a nation in near future. National policies shall be introduced, modified, altered and diversified towards building a skilled human resource, which is the demand of the world economy. People challenge will be more and more challenging with the aging workforce, in whose skills, knowledge and experience that we are depending on. Training of skilled human resources will be the gateway to the success of the nation considering the in-house demand and the global trend.

By adopting more attentive project management procedures, enhancing continuous coordination and direct communication among the parties, effective and proper planning and scheduling and strictly following the prepared realistic schedule, enhancing the human resource of the employees, motivating the employees, managing the knowledge, the NWSDB will be able to overcome the project management challenges in water supply and sanitation sector.

In addition, this paper will provide an opportunity not only to NWSDB, but also its contractors to forecast possible scenarios of critical project management and thereby will be a help to identify common pitfalls so as to eliminate the avoidable and highlight them to management to avoid a recurrence of such phenomena. Further, the management and staff allocated to settling and dealing with such situations will be reduced. Moreover, it will facilitate the NWSDB and/or its contractor to overview the project management challenges in other parties perspective and help each other with their strengths to overcome the other's weakness, since project management, at the end of the day, is a team work.

Project Management with a thorough identification of possible project management challenges and a proven ability to toggle with the challenges leads a project to its success.

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PROJECT MANAGEMENT DASHBOARD OVER PREVAILING TOOLS AND SOFTWARE: A STUDY ON ADDRESSING NINE KNOWLEDGE AREAS

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ABSTRACT

Construction projects represent unique and immensely complex array of interdependent activities that must take place to accomplish project goals. Thus, the nature of construction projects reasoned to complications and ambiguities in the construction process demands the need for Project Management (PM) to fruitful completion of projects. Construction PM uses a range of tools and software to assist the accomplishment of PM knowledge areas which define the critical constraints of a project such include the management of time, cost, quality, risk, integration, scope, communication, procurement and human resource. However, the selection of convenient PM tools and software which fulfil critical requisites in construction projects is problematic. Project Management Dashboard (PMD) is one of PM tools, which contains a variety of quality based project tracking and control metrics. Though PMD is widely practiced in other industries, a lacuna existed under the Sri Lankan construction context.

Hence, this study intended to assess the fulfilment of nine PM knowledge areas by PMD over prevailing PM tools and software. Thus, a hybrid survey approach, including questionnaire survey and the expert interview survey was conducted among PM professionals due to the fact that positivism in the research philosophy. The questionnaire survey analysis emphasised the ineffectiveness of most commonly used PM tools and software in fulfilling critical PM necessities and affirmed that an individual tool cannot effectively address on crucial PM needs. Subsequently, PMD was developed incorporating the essential elements (i.e. physical and financial progress, approval status, issues, risk, labour and general) based on the expert survey findings. Further, the interview survey confirmed the suitability of PMD in addressing critical PM requirements over conventional tools and software used in the Sri Lankan construction industry obtaining the results above the midpoint of the scale. Eventually, it is recommended to utilise PMD, in order to successfully manage construction projects.

Keywords: *Project Management; Project Management Dashboard; Project Management Knowledge Areas*

1. INTRODUCTION

A project is a solution to a problem (Winch, 2002) that has a clear beginning and end and is carried out to achieve established goals within cost, schedule and quality objectives (Haynes and Perry, 1985). In consideration of the construction projects, Walker (2007) defined it as intricate and time-consuming undertakings which have unique and multifaceted nature enhance the risk of the project. Hence, the PM approach is essential to successfully manage construction projects. Mansfield (as cited in Meng, 2012) identified the intricate nature of construction projects necessitate to manage overall critical requirements of the project, in order to successfully accomplish project objectives. PM Institute [PMI] (2008) emphasised the importance of fulfilling nine knowledge areas in PM, which offer a comprehensive guideline to manage projects.

Further, Koppelman and Fleming (2006) emphasised effective PM tools and software are indispensable to manage critical requirements of the project during the construction stage. Furthermore, PM tools and software are imperative to monitor the progress of the project. However, Young (2006) illustrated that conventional PM tools and software generally focused on planning and scheduling of the project, which are not satisfactorily addressing on critical PM requirements in construction. Aaron (2001) stated traditional

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project planning and control tools such as Task list and Gantt charts are not adequate to control large scale projects. Sole reliance on a tool such as MS project is inadequate for tracking and controlling complex and integrated projects. Hence, it is crucial to utilise appropriate PM tools or software, which is capable to address critical requirements of construction projects (Berkun, 2005).

Conventional tools and software are not adequately address critical PM desires. Thus, technically improved software and innovative PM solutions are regularly utilised in an international context. For instance, The PMD is a customised PM information system containing a variety of quality based project tracking and control metrics. The PMD enables the project manager to clearly monitor the 'vital signs' of a project, to identify problems early and to trigger corrective and proactive actions in a timely manner (Aaron, 2001).

Sri Lankan construction industry also necessitates an innovative PM tool to improve the excellence of PM through minimising poor performance. Hence, this study aims at identifying the suitability of the PMD in addressing critical PM requirements over other conformist PM tools and software under the Sri Lankan building construction context.

To achieve the above aim, it was found necessary to achieve the following objectives:

- To identify construction project management and project management knowledge areas.
- To identify the prevailing PM tools and software and its fulfilment of PM knowledge areas.
- To develop PMD, incorporating critical requisites.
- To investigate the suitability of the PMD in addressing PM knowledge areas.

The scope of the study was limited to the building construction in Sri Lanka; therefore the civil engineering construction had been excluded. The paper structure begins in the following sections with a review of literature. The next section presents the research methodology followed by data analysis. The paper finally presents discussions and conclusions of the research study.

2. LITERATURE REVIEW

2.1. THE CONCEPT OF PROJECT

The projects are temporary in nature which contains a definitive start date and end date (Chaudhary, 2005). Each project is specific and unique in nature which contains a specific deliverable aimed at meeting a specific need or purpose (Mantel *et al.*, 2010). Similarly, the PMI (2008) defines a project as "A temporary endeavour undertaken to create a unique product or service".

Different authors have defined the term project in different ways. Nevertheless, there are some general characteristics, which could be identified in most of these definitions. Table 1 recapitulates general characteristics of a project identified by the different authors.

Table 1: General Characteristics of a Project

General Characteristics	A	B	C	D	E	F	G	H	I	J
Projects are unique	x	x	x	x	x	x	x	x	x	x
Projects are goal oriented.	x	x	x	x	x	x	x	x	x	x
Temporary in nature,	x	x	x	x	x	x	x	x	x	x
Defined beginning and a finish	x	x	x	x	x	x	x	x	x	x
Clear life cycle	x		x			x	x			x
Consist with number of separate yet interdependent activities.	x	x	x		x	x		x	x	x
Require a range of resources.	x	x		x		x		x		x
Project delivers unique output.	x			x	x	x		x	x	x
Projects cut across organisational lines.		x		x		x	x			
Creation of new value.				x				x	x	x

Note: A=Project Management Institute, 2008; B=Kerzner, 2001; C=Nicholas, 2001; D=Heyworth, 2002; E=Phillips, 2004; F=Heldman, 2005; G=Chaudhary, 2005; H=Walker, 2007; I=Winch, 2002; J=Woodward, 1997

Nicholas (2001) stated that clear identification of the characteristics of a project would be advantageous to effective management process. Therefore, management of projects is critically important in order to achieve the defined objectives of the project successfully.

2.2. THE CONCEPT OF PM

PM is the planning, organising, directing, and controlling of company resources for a relatively short term objectives, which has been established to complete specific goals and objectives (Kerzner, 2001; Heldman, 2005). Further, Young (2006) defined PM as a dynamic process which utilises the proper resources of an organisation in a controlled and prearranged manner to achieve clearly distinct objectives identified as strategic needs. Furthermore, Chaudhary (2005) summarised that PM involves applying knowledge, skills, and techniques during the course of the project to accomplish the project requirements and the project manager is responsible to ensure whether PM techniques are applied and followed. Moreover, PM engages with different functions which include defining the requirement of work, establishing the extent of work, allocating the resources required, planning the execution of the work, monitoring the progress of the work and adjusting deviations from the plan (Munna and Bjeirmi, 1996).

2.3. PM KNOWLEDGE AREAS

PM involves identifying project requirements, establishing project objectives, managing constraints, and prioritising the needs and expectations of the key stakeholders (Heldman, 2005). Hence, nine knowledge areas of PM are established to address the critical requirements of a project (PMI, 2008). The discussions on nine knowledge areas were tabulated in Table 2 below.

Table 2: Nine Knowledge Areas

Time management	Time management involves defining and sequencing activities and estimating the duration and resource requirements for each individual task (Rosenau and Githens, 2005). Further, Heldman (2005) emphasised that successful time management leads to keep the activities on track and ensure the achievement of target completion. According to PMI (2008) emphasised on five steps in the time management process. They are defining activities, sequence activities, estimate activity resources, estimate activity duration and develop a schedule.
Cost management	Effective cost management is one of the core focus areas in PM since financial resource is a key constraint in a project (Winch, 2002; Kerzner, 2001). Morris *et al*, (2006) identified that cost estimating, cost budgeting, and cost control as the three foremost activities in the cost management.
Quality management	Quality management assures that the project meets its specified requirements (Heldman, 2005). Further, Verzuh (2003) highlighted project quality management as a continuous process throughout the project life cycle which determines quality policies, objectives, and responsibilities. Moreover, quality management, process involves three steps, including plan quality, quality assurance and quality control (Kerzner, 2001; Verzuh, 2003).
Risk management	Project risk management concerned with identifying, analysing, and planning potential threats and opportunities (Heldman, 2005). Further, Heldman (2005) stated that the early identification of risk and uncertainty in a project is extremely important. According to Cooke and Williams (2004), risk management process involves six major steps which follow, risk management plan, identify risk, qualitative and quantitative risk analysis, plan risk responses and monitor and control risk.
Integration management	Integration management involves identifying and defining the project tasks and combining, unifying, and integrating the appropriate process (Berkun, 2005). Further, Rosenau and Githens (2005) stated that the integration is basically focused on making choices to prioritise resources and effort. According to the PMI (2008), integration management comprises seven processes which include, develop project charter,

	develop a PM plan, manage project execution, monitor and control project, integrated change control and close project or phase.
Scope management	This engages in management of the requirements, details and processes (Kerzner, 2001). Moreover, scope management focus on defining the needs, set the expectations, manage the changes and minimise the deviations of the project (Heldman, 2005). With reference to PMI (2008), five important steps in project scope management are identified which take account of collecting requirement, define scope, create work breakdown structures, verify the scope and control scope.
Communication management	Field and Keller (1998) highlighted that effective communication creates a bridge between diverse stakeholders involved in a project, connecting various cultural and organisational backgrounds, different levels of expertise, and various perspectives and interests in the project execution or outcome. Further, communication management in a project team is a process which is illustrated by the PMI (2008) including identifies stakeholders, manage stakeholder expectations, plan communication, report performance and distribute information.
Procurement management	Procurement management processes of procuring products, services, or results externally (PMI, 2008). It is focused on establishing, maintaining and closing relationships with suppliers of goods and services for the project (Phillips, 2004). Furthermore, Project Management Institute (2008) provides four major steps of Project procurement Management, which are plan procurement, conduct procurement, contract administration and close procurement.
Human resource management (HRM)	Project HRM processes ensure human resources are utilised in the most effective, efficient and economical way (Kerzner, 2001) by leading the team, coaching, dealing with conflicts and performance appraisal (Heldman, 2005). According to PMI (2008) emphasises four steps in project HRM which comprising of developing an HR plan, acquiring project team developing a project team and managing a project team.

2.4. CONSTRUCTION PM

Construction projects are unique. It is heterogeneous and enormously complex (Walker, 2007). Clough, Sears, and Sears (2000) specified unique nature of the construction projects amplifies the complexity and the uncertainty. Further, Cooke and Williams (2004) suggested extensive project management techniques are essential to effectively manage construction projects due this complexity and the uniqueness.

Winch (2002) identified the construction PM as the process of controlling the accomplishment of the project objectives utilising the existing organisational structures and resources. Further, Oberlender (2000) emphasised construction PM seeks to manage the project by applying a collection of tools and techniques, without adversely disturbing the routine operation of the company. Fryer *et al.* (2004) suggested that application of PM knowledge areas into construction PM is beneficial to effectively manage the entire process. Furthermore, it is important to utilise all the extensive PM concepts and nine knowledge areas to successfully perform the duties (Oberlender, 2000).

Time, cost and the quality are the primary concerns of clients in the construction industry, which is known as the triple constraints in construction projects (Bennett and Grice, 1990). Hence, the proper project monitoring system is decisive to effectively manage time, cost and quality objectives of the project. Effective monitoring and controlling of project progress is vital as planned in the construction PM process. Harris and McCaffer (2006) described monitoring as the act of checking actual progress against planned schedule, whereas the act of taking decisions to alter the likely future outcome and bringing the project back on the planned schedule is described as controlling. According to Heldman (2005), PM utilises different tools and techniques performed by people to define, organise, and monitor the project activities.

2.5. PM TOOLS AND SOFTWARE

Construction PM is a challenging task with many complex responsibilities. Modern construction PM utilises a number of tools to assist in accomplishing the tasks and executing the responsibilities (Yeung *et al.*, 2009). Some of the tools necessitate supporting computer applications and some can be used manually.

Conlin and Retik (1997) affirmed that an individual tool cannot effectively address on crucial PM needs. Therefore, selection of appropriate sets of PM tools is beneficial for effective construction PM.

PM software is beneficial to manage the project efficiently and keep a track of all the activities in the PM process (Winch and Kelsey, 2005). Further, PM tools have developed from simple spreadsheet products to sophisticated, web-based project information portals (Anbuvelan, 2005). Furthermore, Pryke and Smyth (2006) highlighted that trends in PM software are to move towards web-based systems, which integrate different systems of the project. Besides, PM software capabilities and features vary a great deal among the available packages (Kerzner, 2001). Nevertheless, the variation is more in the depth and sophistication of the features, such as its storage, display, analysis, interoperability, and user friendliness are similar for most software packages (Bayross, 2005). Hence, Tidwell (1992) demonstrated that purpose of the PM software is to make the creative process of outlining and controlling a project, from initial design to start-up, more controllable. Thus, PM software and tools ensure that project would be completed in a timely manner, within budget, and the desired level of quality.

Hence, the existing literature revealed the prevailing construction project management tools and software as tabulated in Table 3 below.

Table 3: Project Management Tools and Software

Project Management Tools		**Project Management Software**	
Work Breakdown Structure	Earned value management	MS Project	MS Excel
Gantt Charts	Scenario Planning	Primavera (P6)	Cost Track
Critical Path Method	Project Reports	Primavera Earned Value Management	American Contractor
Program Evaluation Review Technique	Project Management Dashboard	Primavera Contract Management, Business Intelligence Publisher Edition	Basic Builder
Six Sigma			Construction Manager
Source: Cooke and Williams (2004); Kerzner (2001); Morris and Pinto (2007)		Source: Oracle (2013); Kerzner (2001)	

2.6. *PROJECT MANAGEMENT DASHBOARD*

The PMD has been identified as one of the project management tools in Table 3. PMD is a customised PM information system containing a variety of quality based project tracking and control metrics which enables the project manager to identify the "vital signs" of a project for early identification of issues and to prompt proactive actions in a sensible approach (Aaron, 2001). Further, Kerzner (2001) highlighted that the main purpose of the PMD is to provide accurate information to the right person at the right time using the correct medium in a cost effective approach. Furthermore, Rahman *et al* (2011) affirmed that PMD is advantageous to dramatically reduce the need for financial and operational reports. Thus, it is useful for decision making and improves the performance. Moreover, Aaron (2001) recognised three major advantages of PMD, i.e. concentrating on vital activities of the project, identifying the true status of the project and provides a weekly report on key dimensions of the project. Besides that, the developments of PMD in MS Excel spreadsheets allow users to adopt into the system with a less effort. Hence, the graphical presentation approach is supportive to express the actual status of the project to key stakeholders, including the layman clients (Rahman *et al.*, 2011).

3. METHODOLOGY

An extensive literature review was carried out to investigate concepts of construction PM and theoretical overview of PM knowledge areas. In the consideration of the research philosophy, to a certain extent it is believed that the research is more towards to the positivism end. It is a fact that, the existing theory is used to develop a hypothesis on the determination of nine knowledge areas through PMD. Hence, it is subsequently tested in whole or part, or refuted, leading to the further development of the theory (Saunders *et al*., 2009). Moreover, positivists believe that the reality is stable and described from an objective point of view (Levin, 1988). Hence, the taxonomy of research methodologies has identified that survey approach is suitable for the positivism (Galliers, 1991).

Thus, a questionnaire survey was then carried out among a sample (50) of PM professionals in the Sri Lankan construction industry. This was intended to identify commonly used PM tools and software in the Sri Lankan building construction industry and the fulfilment of nine knowledge areas. Respondents' self-assessment was rated according to the Likert scales given below.

Likert scale 1: Frequency of Using the Tool or Software in Sri Lankan Construction Context

1	**2**	**3**	**4**	**5**
Rarely	Occasionally	Sometimes	Often	Every time
1-20%	21-40%	41-60%	61-80%	81-100%

Likert scale 2: Fulfilment of Nine Knowledge Areas

1	**2**	**3**	**4**	**5**
Strongly Agree	Agree	Intermediatel	Weakly Agree	Very Weakly

Thus, Likert-type data analysis was based on the significant measurement by using the Relative Importance Index (RII) to rank the frequency of using the tools or software in construction PM and the fulfilment of nine knowledge areas. Further, Mode and Median were individually calculated for each knowledge area for the validation of RII results. The following formula was used to compute RII from the data where the RII shall change from 0% to 100%. Weightage was as per the Likert scale weighting 0 being the least and 5 being the highest.

$$RII = [(W.n) \text{ x } 100] / A.N \qquad \text{(Eq.01)}$$

Where, W = Constant expressing the weighting given to each response, A = the highest weighting, N = the frequency of responses, N = Total number of the responses.

Subsequently, the PMD was developed incorporating the main elements generated from the expert survey analysis. The respondents were those who retained the experience of using the PMD in the foreign construction projects. Finally, an interview survey was carried out among a sample (10) of PM experts to identify the suitability of PMD in fulfilling critical PM requirements over conventional tools and software. Mode value is used to analyse the frequency of responses to conclude the suitability of introducing the PMD to the Sri Lankan building construction industry.

4. QUESTIONNAIRE SURVEY DATA ANALYSIS

A preliminary questionnaire survey was carried out among 50 individuals in the construction industry and only 43 questionnaires were responded. Hence, this analysis is based on the responses of 43 respondents and the rest of the 7 considered as non-respondents. Hence, the response rate for this preliminary questionnaire survey was 86%. Questions were mainly distributed among the project managers, site engineers, chartered engineers, quantity surveyors, chartered quantity surveyors practicing in the Sri Lankan construction industry. The minimum experience requirement for the respondents was 3 years in the construction industry. 56% of the respondents had more than ten years' experience. 31% of the respondents had 5-10 years' experience and 13% of them were in the category of 3-5 years' experience.

4.1. RANKING PM TOOLS AND SOFTWARE WITH THE RII

The most commonly used PM tools and software in the Sri Lankan building construction industry is tabulated in Table 4. MS project has gained 93% of relative importance and marked as the mostly used software in the Sri Lankan building construction industry.

Table 4: Mostly Practiced Tools and Software

PM Tools/Software	RII	RANK	% of respondents
MS Project	93%	1	100%
Project reports	83%	2	100%
Critical path method (CPM)	75%	3	100%
Spreadsheet schedules	73%	4	100%
Gantt charts	69%	5	100%
MS Excel	61%	6	100%
Earned value management (EVA)	55%	7	95%
Work breakdown structure	51%	8	100%
Program evaluation and review technique	50%	9	86%
Primavera (P6)	41%	10	88%

However, Primavera (P6) has gained 41% relative importance and ranked as 10. The Relative importance of top 10 tools and software diverges between 52% range. Project reports are the most commonly used PM tools in the Sri Lankan building construction industry, gaining a relative importance of 83%. An overall ranking of the Project report is 2. The difference between top 2 ranks is 10%. CPM is ranked as the 3 where the difference of RII between rank 2 and 3 is 8%. Relative importance of seven tools and software has dispersed between 25% range, which is from 75% to 50%.

On the other hand, Primavera Sure Track, Primavera, EVA, PMD, Primavera (P3), Six Sigma, Scenario planning, Primavera Contract Management, Cost Track and Basic Builder ranked as the least practicing PM tools and software in the Sri Lankan construction context. Primavera Sure Track has gained 5% relative importance and Primavera EVM has gained RII about 4%, where the percentage of respondents practiced is 19% in both the software while other tools and software has gained negligible values.

4.2. FULFILMENT OF NINE KNOWLEDGE AREAS BY THE PM TOOLS AND SOFTWARE

Mostly practiced tools and software identified in the section 1 were selected for the further analysis. Therefore, top ten PM tools and software were individually analysed to identify the fulfilment of nine knowledge areas according to the Likert scale 2.

According to the analysis Primavera (P6) has the highest influence on ***time management*** over other tools and software gaining the highest RII which is 90%. Mode and the Median indicate "high effect". Secondly, MS Project has gained 84% RII for time management and the Mode and the Median value of indicate a "moderate effect". Project reports, critical path method, spreadsheet schedules, Gantt charts and PERT have a significant effect on time management of construction projects where all the tool have gained more than 70% RII. EVA has the highest RII for ***cost management***, which is 73%. Mode and the Median indicate a "moderate effect". Project reports have gained the highest RII for ***quality management***, which is 46%. Mode and the Median of other tools and software vary in between "No effect" to "Minor effect. Gantt charts and project reports have gained the highest RII for ***integration management***, which is 51%. Mode and the Median of all tools and software indicate a "Minor effect". Gantt charts have the highest RII for ***scope management***, which is 65%. Project Reports have gained the highest RII for ***HRM***, which is 44%. Mode and the Median of all tools and software indicate a "Minor effect". Primavera (P6) has the highest effect on ***communication management***, gaining 55% of RII and Mode and the Median indicate a "Neutral effect". Critical path method has the highest effect on ***risk management***. It has gained 44% relative importance and Modes and the Medians of all the tools and software vary in between "No effect" to "Minor effect. MS Project has the highest effect on ***procurement management.*** RII of MS Project for procurement management is 40% and Mode and the Median indicate a "Minor effect". The results are then summarised in Table 5, ranking the best five PM tools and software which fulfil knowledge areas comparatively.

Table 5: Top Five PM Tools and Software Fulfilling Each Knowledge Areas

PM Knowledge areas	Best PM tools and software				
	1	2	3	4	5
Time	Primavera (P6)	MS Project	CPM	Gantt Charts	PERT
Cost	EVM	Primavera (P6)	MS Excel	Project reports	PERT
Quality	Project reports	Spreadsheet	MS Excel	Primavera (P6)	WBS
Risk	CPM	Primavera (P6)	PERT	MS Project	EVM
Integration	Project reports	Gantt Charts	CPM	WBS	Spreadsheet
Scope	Gantt Charts	Primavera (P6)	MS Project	CPM	Project reports
Communication	Primavera (P6)	Project reports	MS Project	CPM	Gantt Charts
Procurement	MS Project	Spreadsheet	CPM	MS Excel	Primavera (P6)
HR	Project reports	Primavera (P6)	CPM	Gantt Charts	WBS

According to the Table 2, Primavera (P6) has the highest influence on time management and communication management, over another mostly practiced PM tools and software. Further, Primavera (P6) also gained the second highest RII for cost management, risk management, scope management and HRM. Furthermore, Primavera (P6) attained the fourth highest RII for quality management and fifth highest RII for procurement management. Hence, Primavera (P6) fulfils most of knowledge area over other tools and software. EVM is the best solution for the cost management of the project. Project reports have a significant effect on quality, integration, and human resource management of the projects, which was identified as the best solution for the above mentioned three knowledge areas. Gantt charts are a perfect solution for the scope management where CPM is finest for management of risk compared with the other tools and software. MS Project, which was identified as the most commonly used PM software, is the best solution for the procurement management of the project.

5. DEVELOPMENT OF THE PMD

A structured questionnaire was developed based on the literature findings and existing dashboards used for international projects. Structured questionnaire was distributed among three experts for construction PM, who have used PMD for the international projects. The data generated from the expert survey revealed the most important elements which should be displayed in the PMD under the six headings such as, physical and financial progress, approval status, issues, risk, labour and general.

The mode was used to analyse the data collected through the expert survey. The results generated through the analysis, concluded that more than 67% of the respondents marked the tabulated elements under 6 categories as “Necessary” and “Usually used” in the PM. Thus, concluded the proposal of PMD and its requisite features to be incorporated into the dashboard under the Sri Lankan context. Subsequently, PMD was developed in a MS Excel format based on the above information and illustrated in Table 6.

Table 6: Analysis of Expert Survey

Group		Information	Degree of Necessity			Extent of Use		
			Unnecessary	Optional	Necessary	Not Used	Sometimes	Usually Used
Physical and Financial Progress	1	Summary of the physical progress of the project.			100%			100%
	2	Graphs comparing planned progress with the actual.			100%			100%
	3	Summary of the financial progress.			100%			67%
	4	Summary of the project payment status.			100%			100%
Approval Status	5	Summary of the material submittals of the project.			67%			67%
	6	Summary of the shop drawings submissions.			67%			100%
	7	Summary of the method statements submissions.			67%			67%
Issues	8	Summary of the current project issues.			100%			100%
	9	List of issues significantly impact on critical activities.			100%			100%
	10	List of issues highly impact on next week construction.			100%			100%
	11	Identification of responsible parties for project issues.			100%			100%
Risk	12	Summary of major risks of the project.			100%			100%
	13	Impact on time and cost due to the major risk factors.			100%			67%
Labour	14	Summary of the labour productivity.			100%			100%
	15	Comparison between planed labour force with actual.			100%			100%
	16	Indication of a labour shortage.			100%			100%
General	17	Summary of earned value analysis.			67%			100%
	18	Photographs indicating the actual status of the project.			100%			100%
	19	Summary of the next week major activities.			100%			100%

5.1. OVERVIEW OF THE PMD

PMD contains a number of data input sheets and summarised data are displayed in the dashboard under key sections as illustrated in Figure 1. The dashboard provides a high quality user interface that displays the information in a graphical form using a variety of elements including charts, tables and gauges. These elements improve the effectiveness and efficiency in decision making process where time spent on data analysing would be reduced (Malik, 2005). Therefore, PMD necessitate a certain number of supporting data entry sheets in order to provide summarised information to the dashboard sheet.

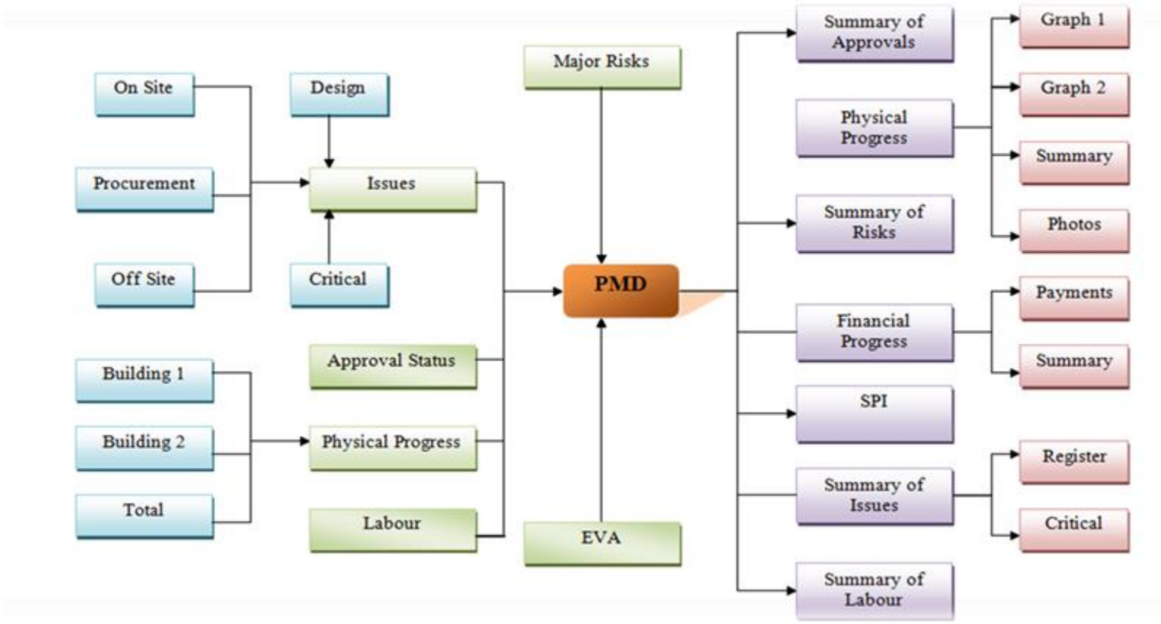

Figure 1: Basic Structure of PMD

6. INTERVIEW SURVEY ANALYSIS

6.1. SUITABILITY OF PMD IN ADDRESSING CRITICAL PM REQUIREMENTS

The summarised responses for the suitability of PMD in addressing critical PM requirements of construction projects together with other merits of PMD, is tabulated in Table 7.

Table 7: Analysis of the interview survey- Suitability of PMD

	Description	Strongly Agree	Agree	Intermediately Agree	Weakly Agree	Very Weakly Agree
	Time Management					
6	Managing the time of the project compare to commonly used scheduling software (i.e. Ms.Project).	90%	10%	-	-	-
7	Identifying key stakeholders' responsibilities to avoid delays.	10%	90%	-	-	-
8	Identifying the causes for time delays in advance.	50%	50%	-	-	-
9	Avoiding time delays by setting up proactive actions	70%	30%	-	-	-
	Cost Management					
10	Indicating the cost overruns of the project.	-	50%	50%	-	-
11	Assisting to manage the cost of the project.	-	80%	20%	-	-
12	Proactive decision making by Project managers to avoid cost overruns due to the early identification of the issues.	-	70%	30%	-	-
	Quality Management					
13	Assisting to identify project quality issues.		80%	20%	-	-
14	Proactive decision making by Key stakeholders to avoid quality related problems due to early identifications of issues.	30%	70%	-	-	-
	Risk Management					
20	Quantifying the major risk factors of the project.	10%	90%	-	-	-
21	Noticing the major risks in advance.	-	80%	20%	-	-
22	Managing the major risk factors of the project.	-	90%	10%	-	-

	Description	Strongly Agree	Agree	Intermediately Agree	Weakly Agree	Very Weakly Agree
	Integration Management					
23	Assisting to combine and integrate different processes.	-	40%	60%	-	-
24	Prioritising the resources utilisation effectively.	20%	70%	10%	-	-
25	Assisting to monitor and control the project.	10%	90%		-	-
26	Integration management of the project.	-	50%	50%	-	-
	Scope Management and Communication Management					
27	Identifying and managing the project scope.	10%	50%	40%	-	-
28	Distributing and sharing information among stakeholders.	20%	80%	-	-	-
29	Collecting, storing and retrieving information of the project.	10%	90%	-	-	-
	Procurement Management and Human Resource Management					
30	Identifying supplier related issues in advance.	-	70%	30%	-	-
31	Assisting the procurement management of the project.	-	70%	30%	-	-
32	Assisting to manage the labour requirements of the project.	-	80%	20%	-	-
33	Proactive decision making to avoid HR issues.	10%	90%	-	-	-

At the first instance, the overall picture of Table 4 possesses an optimistic conclusion of the suitability of the PMD under the Sri Lankan building construction industry which illustrated the responses ranged between strongly agree and intermediately agree. Hence, the testing of the hypothesis on the determination of fulfilling the nine knowledge areas through PMD has been certain.

Further, most of the interviewees strongly agreed about the capability of PMD to manage the time of the project. This is advantageous for key stakeholders of the project to identify their responsibilities in order to avoid time delays. Furthermore, PMD addresses on cost and quality management aspects of the project in a better way. Moreover, PMD is capable to identify the critical issues of the project at the earliest stage and subsequently proactive decisions can be implemented. Especially, key stakeholders can determine their responsibilities in each of project issues and corrective decisions can be taken. Besides, PMD accomplishes critical requirements of the integration, scope, risk communication, human resources and the procurement management of the project. These critical areas were not addressed appropriately by the commonly used PM tools and software of the Sri Lankan building construction industry.

Beyond the consideration of assessing the knowledge area fulfilment, the questionnaire is extended in assessing the general merit of using PMD under the Sri Lankan context. As a progress monitoring tool, 70% of the respondents have agreed that PMD delivers a clear snapshot of the project status. Further, 60% have agreed that the PMD is a decision making tool which highlights the relevant information. Furthermore, PMD is beneficial to monitor the physical and the financial progress of the project, which is vital to identify the exact status of the project. At the point of view of user friendliness, the format of the PMD is simple and easy to use without specific knowledge. In emphasis, 70% of the respondents have strongly agreed that simplicity inherent in the PMD due to the use of MS. Excel interface. It is often alleged that, the PMD identifies project issues in advance. Subsequently, PMD determines the responsibility of key stakeholders in each of project issues, identifying issues with higher impact. Besides this, over 90% of the respondents have agreed that PMD is a feed forward PM tool. However, it is commonly agreed the need of a separate operator in order to collect data from different parties and the contemporary review to the PMD. Finally, analysis of the interview survey emphasised the applicability of the PMD in the Sri Lankan context which has derived the 60% strong agreement to the introducing of PMD in the Sri Lankan construction context fulfilling the most of PM knowledge areas over conventional tools and software use in Sri Lankan construction context.

7. CONCLUSIONS AND RECOMMENDATIONS

The PM is a dynamic process which utilises the project resources in a controllable and prearranged manner to accomplish the project objectives. Critical requirements defined in the nine knowledge areas of the PM must be considered for the achievement of project objectives, such include management of time, cost, quality, risk, integration, scope, communication, procurement and HR. Since the construction PM concepts are derived from the general PM concepts, construction PM accomplish the project objectives by utilising the existing organisational structures and resources. However, the unique nature of the construction projects amplifies the complexity and the uncertainty. Therefore, extensive PM techniques which covered the critical project requirement are essential to successfully manage construction projects.

The questionnaire survey analysis revealed that MS Project as the most popular PM software in the Sri Lankan construction industry. However, in terms of fulfilling PM knowledge areas Primavera (P6) had superseded other mostly practicing PM tools and software. Yet, the results revealed that, neither PM tools nor software in the Sri Lankan construction industry effectively addressing all the nine knowledge areas of the PM. Most of the tools and software concentrated only time and cost parameters. Thus, Sri Lankan construction industry necessitates an innovative PM tool or software to improve the excellence of PM through addressing all critical requirements. Afterwards, the proposal of PMD is built incorporating the important elements under the six headings such as, physical and financial progress, approval status, issues, risk, labour and general. Next, PMD was developed in an MS. Excel format based on the above information with a number of supporting data entry sheets in order to provide summarised information to the dashboard sheet. The PMD provides a high quality user interface that displays the information in a graphical form using charts, tables and gauges.

Finally, the expert survey results derived the suitability of the PMD to accomplish the nine PM knowledge areas where the respondents possessed the optimism for PMD. Mainly, PMD has contributed to the time management. Moreover, the other entire PM knowledge area fulfilment through PMD had been agreed. Thus, the initial hypothesis under this research study has become certain. Moreover, PMD is beneficial for the physical and financial progress monitoring of the project, managing approval status, and identification of project issues. Hence, it cannot be denied that the PMD is recommended to use for construction PM, which is capable to execute the critical PM requirements. However, the inadequacy of knowledge on the PMD would be a barrier under the Sri Lankan context. Therefore, it is important to promote the concept among the PM professionals through CPD programmes and by other means of knowledge sharing sessions.

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PROJECT RISK MANAGEMENT BY SMALL-SCALE CONTRACTORS IN SRI LANKAN BUILDING CONSTRUCTION

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ABSTRACT

The construction industry remains one of the most dynamic and challenging industries in the world due to the complexity of its production process. This makes it subject to more risk and uncertainty than other industries that make it difficult for newcomers as well as small-scale contractors to be sustainable in the construction industry. The identification and assessment of new risks along with their interrelationships and coming up with the appropriate responses to new risks is a cumbersome process entailing some degree of complexity. The present research focuses on the identification of critical risks, the allocation of those risks among the small scale contracting parties, and the determination of appropriate response measures to managing the risks thus identified.

The study first elicited the views of senior construction professionals on risks in the small-scale contractors in a preliminary survey prior to carrying out a questionnaire survey among a selected group of small-scale contractors. Sixteen (16) significant risk factors were identified and evaluated by using the Relative Importance Index (RII). The research further worked out the allocation of risk among the contracting parties and the appropriate response measures. On the basis of the research outcomes, the study proposes a risk management framework for appropriate risk management among small-scale contractors. The findings reveal the importance of paying attention to risk aspects by small-scale contractors in construction projects and identifying the problems relating to inadequate knowledge or techniques of small-scale contractors that may pose barriers to it. The paper proposes proper education and training of such contractors as one measure to overcome the identified barriers. It recommends the hiring of risk management consultants and the bearing of the risk by the party that has most control over it rather than passing it on to the other party as ways to control risks.

Keywords: *Response Measures; Risk Management; Significant Risk Factors; Small-Scale Contractors; Sri Lankan Building Construction Industry.*

1. INTRODUCTION

There is a significant demand for condominiums in Colombo metropolitan area due to high population density, scarcity of land availability and soaring prices of property particularly in urban areas of the country (Gunawardena and Samarajeewa, 2006) and convenience of buying a condominium rather than constructing a house (Senaratne *et al.*, 2006). Hewamanna (2005) identified that there is a rapid expansion in the construction and sale of condominiums in Sri Lanka during the past few decades. Especially in Colombo and suburbs, the apartment market is mainly vigorous because there is a huge demand for urban living (Wasala, 2007). However, in long-term sustainability of this industry would, certainly, depend on the ability of the property developers to meet the needs and expectations of the end users or the occupants (Gunawardena and Samarajeewa, 2005). Kerti (2014) sated that construction of apartment or condominium is a means of supporting the development options tourism in tourist destination areas which have limited land for construction of tourism facilities. According to the Apartment Ownership Law Act No. 39 of 2003, condominium is a property comprising of land with a building or buildings more than one story and having more than one unit residential or non-residential accommodation.

The population of a country can be generally in three groups according to the income levels as high, medium and low (Central Bank, 2009). The residential sector of Sri Lanka is a major area that shows variations

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according to the above three levels. Types of the condominium available in Sri Lanka mainly depend on facilities offered such as swimming pool, gymnasium, restaurant and internal and external finishes and fittings used. (Senaratne *et al*., 2006). As Wijeyeweere (2004) mentioned, based on the available facilities, finishes and fittings, condominiums can be categorised in to super luxury, luxury, semi luxury and the utility condominiums. The government is the main developer for utility condominiums in Sri Lanka. Therefore, government servants, low-income earners and the shanty dwellers have been the beneficiaries of such state sponsored projects. Siriwardena (2001) stated that low income condominiums have become the most viable alternate homeownership method to provide accommodation for low income earners and resettlement of shanty dwellers with the upsurge of land values in urban areas. Even though living in these condominiums provide many benefits for low income groups in the society, as found by Lorensuhewa (2009) various issues existed with the low income community in Sri Lanka. According to the findings of Gunawardena and Samarajeewa (2005), significant differences could be seen between the expectations of occupants in condominium and understanding of the developers. As stated by the same authors, this situation is more worsen in the public sector condominium developments. Gunawardana and Samarajeewa (2006) pointed out that occupant satisfaction is very significant for the progress and existence of the condominium industry. Therefore, identifying the issues in condominiums designed is essential to provide better living environment for the users although few research studies conducted in the particular area. Thus, this study investigates the existing living condition of low income condominiums in Sri Lanka in terms of user satisfaction. This study was limited to the low income condominiums which are located in the Colombo district. The construction industry constitutes a key component in a nation's economy and affects by the Gross Domestic Product (GDP) of any country (Enshassi, Al-Hallaq, and Mohamed, 2006). Moreover, it is one of the most dynamic, risky, and challenging businesses (Mills, 2001). Because construction projects are commenced in complex, dynamic and uncertain environments, they are prone to many types of risks (Baloi and Price, 2003), which inevitably affect the cost, time and quality of the construction project.

Risk is defined as exposure to the possibility of economic or financial loss or gains, and the physical damage or injury or delay as a consequence of the uncertainty associated with pursuing a course of action" (Chapman and Cooper, 1987, p.238). Risk and uncertainty can potentially carry negative consequences for some construction projects (Burchett, Tummala, and Leung, 1999). Furthermore, it can affect productivity, quality, performance, and the project budget. However, Burchett, Tummala, and Leung (1999) have asserted that risk can be minimised, though it is inherent and difficult to treat, if an appropriate management framework can be arrived at informed by both a theoretical and practical sense (Wang, Dulami, and Aguria, 2004).

Risk management is an essential part of the decision making of construction firms according to Liu, Flanagan, and Li (2003). They go on to say that risk management creates awareness of uncertainty, risk qualification, controllable risk management and of how to minimise the impact of uncontrollable risk by risk allocation/apportionment. Jaafari and Anderson (1995) list three steps to risk management: identification and analysis of the risk, and response to the risk. Flanagan and Norman (1993) asserted that risk identification is a key stage in risk management as risks cannot be managed unless identified. Identifying each source of risk and their components allows the risk element to be separated and distinguished from others (Bajaj, Oluwoye, and Lenard, 1997). According to these authors, consideration of factors influencing each risk will simplify its analysis and management. The next step in risk management is the analysis of associated risks where the effects of major risks that have been identified are first quantified and then analysed in order to determine both the impact and probability of each risk (Mills, 2001). The final step in risk management is risk response planning which is a process of determining the appropriate responses to the risks that are screened and analysed quantitatively (Schatteman, Herroelen, and Vonder, 2008). These authors have further argued that upon identifying probability of exposure to a particular risk and quantifying its impending consequences, the next step is to deploy acknowledged appropriate strategies such as risk probability reduction, risk avoidance, risk impact reduction and risk transfer. For Quayle (1999), therefore, risk and uncertainty are inherent in all construction work no matter what the size of the project though the size of the project is a key indicator in the categorization of contractors.

Distinctions can be made between contractors on the basis of variables such as the size of the annual turnover, capacity, and capability (Dlungwana and Rwelamila, 2003). A small-scale contractor is generally defined as someone with limited capital for investment, who may need financial and managerial support to effectively run his or her business (Sibanda, 1999). However, industry professionals highlighted the importance of creating an enabling environment for small-scale contractors which includes the removal of barriers to their market entry and for their growth and sustainability. Part of the enabling process may be to offer small-scale contractors support, which will facilitate access to essential resources for them to start and sustain their businesses (Sibanda, 1999). Many small-scale contractors experience difficulties in obtaining funds from financial institutions to finance their business due to the high levels of bankruptcy in the industry(Miles, 1979).Though the initial capital for the business must come from the contractor, many small-scale contractors experience difficulties in obtaining funds from financial institutions to finance their business due to the high levels of bankruptcy in the industry(Miles, 1979).In addition, a majority of small-scale contractors in developing countries have very limited funds and are therefore seldom able to provide the necessary fixed assets as guarantees (Ofori, 1991). Since small-scale contractors operate on very tight budgets, when they make a loss on one project, they tend not to have sufficient resources to continue in business, thus paving the way towards high risks to small-scale contractors in the business (Stretton, 1984).

The risks faced by small-scale contractors in the construction industry are many and varied such as financial risk, managerial risk, technical risk, and political risk. Small- to medium-scale businesses are exposed to risks all the time where they may directly affect day-to-day operations and decrease revenue or increase expenses, the impacts of the said risks ultimately being severe enough to result in failure in the business (CPA Australia Ltd, 2009). However, Sri Lankan small-scale contractors are said to face similar challenges in the short term as they struggle to sustain themselves in the construction industry due to managerial inadequacy, inefficiency, incompetence and inexperience. This makes it difficult for small-scale contractors to secure new opportunities in the industry. There is therefore a need to properly manage risk in order to achieve stability and success in the long run for local small-scale contractors. The present study identifies the risks and risk management strategies for small-scale construction in Sri Lanka and develops a risk management framework to mitigate risk that will result in successful operation of the business in current practice.

2. RISKS MANAGEMENT BY SMALL-SCALE CONTRACTORS: LITERATURE REVIEW

2.1. IDENTIFICATION OF RISKS FACED BY SMALL-SCALE CONTRACTORS

Risk identification is the first step in risk management process (Andi, 2006; Ling and Hoi, 2006; Kayis and Amornsawadwatana, 2007). According Wang and Chou (2003) and Marques and Berg (2011), risk identification and risk allocation are influential factors in risk management while Hertz and Thomas (1984) define risk identification as risk diagnosis. Thus, Heldman (2005) sees the risk identification process as involving the identification and documentation of all the potential risks that might impact the project and their characteristics. Following sections identify imperative risks in building construction.

2.1.1. FINANCIAL RISK

Dada and Jagboro (2007) identified finance as one of the main risk factors faced by small-scale contractors. Edwards and Bowen (1998) categorized it as capital supply, interest rates, credit ratings, cash flows and rentals. Many small contractors experience difficulties in obtaining loans from financial institutions to finance their business due to the high levels of bankruptcy in the industry, which means that the initial capital for the business must come from the contractor (Miles, 1979). In addition, most small and medium contractors in developing countries have very limited funds and they are seldom able to offer the necessary fixed assets as collateral (Ofori, 1991). Since small contractors operate on very tight budgets, when they make a loss on one project, they tend not to have sufficient resources to continue in business (Stretton, 1984).

2.1.2. LEGAL RISK

The legal risk, as categorised by Edwards and Bowen (1998), has to do with contract clauses, regulations and codes. According to Tchankova (2002), the legal system imposes a risk because of contract flaws that may result in breaking current or new local laws relating to the environment. Han and Diekmann (2001) and Wang, Dulaimi, Fadhil, Qing and Yousuf (2004) have identified laws relating to environmental protection, changes in such laws, law enforcement, different codes and contract clauses, and differences of opinion with regard to dispute resolution as the legal risks faced by small-scale contractors.

2.1.3. Technical Risk

Manelele and Muya (2008) argued that lack of technical advice was one of the risks in project initiation where design changes and construction methods are the major risks factors. Edwards and Bowen (1998) included design failure, equipment and systems failure, estimation error, and collisions and accidents among the technical risks. The findings of a study by Santoso, Ogunlana and Minato, (2003) have endorsed the aforementioned technical risks.

2.1.4. Political Risk

According to Lester, (2007), internal politics are an inherent feature of all organisations which may result in differences of opinion and attitudes among the different stakeholders. Tchankova (2002) highlighted how the ruling party of a nation can affect organisations in many ways because of differences in attitudes and policies towards businesses. Thus, Harinarain, Othman and Pearl (2008) identified government authorities as a source of risk to contractors with changes in government and government policies carrying the potential to adversely affect the success of the project.

2.1.5. Managerial Risk

According to International Labour Organisation (ILO, 1987), defficiency in planning and management skills is said to be one of the biggest problems for small-scale contractors. In developing countries in particular, the local construction industry lacks the capacity and capability to undertake large construction projects, which results in the continual domination of expatriate construction companies in all major construction projects of such countries. Consequently, smaller companies find it hard to acquire experience in their chosen type of project (Jannadi, 1997), thus perpetuating a situation of local contractors who continue to have limited management and technical skills (Ofori, 1991) that negatively influence their chances at bidding(Stretton, 1984) and, performance (Ofori, 1991). This in turn impacts the skills and experience of young graduates working in the industry" (Lewis, 1984).

2.1.6. Communication Risk

Though communication among management and staff in small firms tends to be good, sometimes the poor communication skills of the manager can pose a problem for cordial relations between management and staff (Fryer cited in Wasi, Bridge, and Skitmore, 2001). There is often no means of communication between the workers on site and the contractor's office. Urgent site problems, therefore, cannot be solved immediately The ILO (1987) has further noted that the level of supervision by the client too can affect the performance of the contractor. Thus, if the client supervisor is not qualified, or where there is no effective communication between the contractor and the client, this may result in the contractor doing remedial work, which can be very costly for small contractors reducing profit margins and putting a strain on cash flow.

It is clear that risk identification is an important process that identifies the severe risks in a project. In addition, the risk identification process should highlight significant risks, which should be selected for further analysis (Adams, 2008).

2.2. Risk Analysis and Response

Risk analysis is the vital link between risk identification and risk response (Al-Bahar and Crandall, 1990). Risk analysis is defined as the evaluation of the impact of the risk to the project (Wang, Dulaimi, and Aguria, 2004) while as the next step, Akintoye and Macleod (1997) identify risk response as risk allocation. A risk shall be allocated to a particular party, which has the competence and expertise necessary to assess the risk fairly in order to control or minimise the same (Fisk, 1997). Andi (2006) however claims that, risks can merely be transferred or shared from one party to another through contract clauses. Once the risks of a project have been identified and analysed, it will enable the stakeholders to adopt appropriate risk response strategies to cope with the identified risks. Fan *et al.* (2008) have stated that risk response identifies, evaluates, selects and implements strategies in order to reduce the likelihood of occurrence of risk events and/or to lower the negative impact of those risks to an acceptable level.

2.3. SIGNIFICANCE OF RISK MANAGEMENT FOR SMALL-SCALE CONTRACTORS IN SRI LANKA

Satisfaction is referred to as a criterion for evaluating the quality of the residential environment by measuring the effect of perception and assessments of the objective environment upon satisfaction (Altaq and Gzsoy, 1998). As Choudhury (1997) stated residential satisfaction in an apartment is a measure of the capability of the living environment as evaluated by the occupants. It is documented several methods can be used to identify or measure the occupants satisfaction such as formal marketing research, through experience, feedback on the completed projects (Liu, 1999; Ozaki, 2003). Post-occupancy evaluation (POE) is a platform for the systematic study of buildings once occupied, so that lessons may be learned that will improve their current conditions and guide the design of future buildings. Yirga (2012) mentioned that post occupancy management is one of the most pressing challenges with the condominiums as most of the design principles are not well configured and practiced. However, most of property developers seem reluctant to spend much time carrying out such evaluation after a project has been finished. As Gunawardena and Samarajeewa (2006) emphasised, the sustainability of any product lies in its ability to satisfy customer needs continuously. Thus, conducting surveys to identify occupants' satisfaction in condominium life is essential for sustain the properties for a long time. The literature review makes it evident that extensive research has been undertaken in the field of risk management for construction projects. Though studies that focus on some aspects of risk management are available, there is a dearth of research that undertakes a comprehensive assessment of risk management in small-scale construction. However, it is noteworthy that small-scale contractors are higher in number than large-scale contractors in developing countries such as Sri Lanka which make it difficult to discount their contribution to economic growth and makes it imperative. Though Wasi, Bridge, and Skitmore, (2001) and Thwala and Mvubu (2008) have studied the challenges and problems facing small-scale construction in other countries, the findings do not quite suit the Sri Lankan construction industry due to the distinctive character of the construction industry in Sri Lanka. In addition, the afore-mentioned studies do not offer clear-cut explanations of risk in small-scale construction and do not clearly establish risk management by small-scale contractors. However, their findings can be used to guide the present research which studies risk management practices in the Sri Lankan construction industry. Developing countries like Sri Lanka need better managerial tools to manage risk, especially in small-scale construction. Thus, the present study aims to identify and evaluate risk management in small-scale construction in the Sri Lankan construction industry.

3. METHODOLOGY

A comprehensive literature review was carried out to configure the background to the research problem and to prepare the preliminary survey guide line. The literature categorised the risk factors into groups under financial risk, legal risk, technology risk, political risk, managerial risk and communication risk using 23 risk factors. Perera, Rathnayake and Rameezdeen (2008) identified some risk response techniques, barriers to their implementation and solutions to overcome the barriers in road construction projects within Sri Lanka which helped frame the preliminary survey guideline of the research. A questionnaire survey was used for preliminary data collection and was conducted with 3 experts from the industry who have more than 20 years of working experience in order to validate the information gathered from literature to the Sri Lankan context. The preliminary survey added 7 new risk factors to the list while 3 were removed from the documented risk factors gathered from the literature review because they were found not to be relevant to small-scale contractors in Sri Lanka (refer Table 1). ICTAD registration, new construction technology, less professional involvement, shortage of labour, and increasing competition in the industry were added to the list taking into consideration the inherent problems faced by small-scale contractors in Sri Lanka. Of the 42 numbers of questionnaires distributed to small-scale contractors in the survey, 36 completed questionnaires were returned to the researchers.

Table 1: Identified Risk Factors

1.0 Financial Risk	2.0 Legal Risk	3.0 Technical Risk
Capital supply	Environmental protection	Design failure/changes
Interest rates	Change in law	Estimation errors
Credit ratings	Law enforcement	Collisions and accidents
Cash flows	Different codes and contract clauses	Material availability
Rentals	Different dispute resolution methods	Equipment availability
Increasing competition	ICTAD registration	Construction process/method
	Occupational health/safety	Construction site
		Ground conditions
		New construction technology
4.0 Political Risk	**5.0 Managerial Risk**	**6.0 Communication Risk**
Change of government	Lack of managerial skills	Effective communication between the contractor and the client
Change of government policy	Low construction productivity	Poor communication (language problem)
Regulations	Less professional involvement	
Demand of bribe or commission by politician	Shortage of labour	

- Added to list - Removed from list

The questionnaire elicited information on the frequency of occurrence and impact of identified risk factors of small-scale construction projects by using the 1-5 Likert scale. Furthermore, it focused on the allocation of small-scale construction risk factors in order to find out whether the risk factors are allotted to contractors or to clients and to discover the percentage in terms of allocation of risk factors to each party. Moreover, it covered the appropriate response measures commonly used in the construction industry and the suitability of application of those measures in the Sri Lankan construction industry. The questionnaire focused lastly on the barriers to the risk management process and solutions to the barriers. Subsequently, the Relative Importanceindex techinique was selected for the data anlysis using the following equations:

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

Where, w is the weighting given to each factor by the respondents, ranging from 1 to 5, A is the highest weight (i.e., 5 in the study) and N is the total number of samples.

Reliability testing is important for any research of this nature. Hence, Cronbach's alpha method is used to check the reliability of the data set which is expressed by a number between 0 and 1 (Tavakol and Dennick, 2011) and measures how each individual element in a scale correlates with the sum of the remaining points.

4. ANALYSIS AND FINDINGS

4.1. SIGNIFICANT RISK FACTORS

The questionnaire gathered data the frequency of occurrence (likelihood) of risk factors and their impact on the objectives of projects. For the analysis, the significant risk factors were identified and both their frequency of occurrence and impact on the objectives of projects were considered. Since a rating value is necessary for identifying the momentous risks in small-scale construction projects, the collected data from the questionnaire was analysed in three stages as follows:

- Calculation of Relative Importance Index (RII) of likelihood of identified risks;
- Calculation of Relative Importance Index (RII) of impact of those factors;
- Multiplication of the above indexes to get the rating value.

Factors which fulfil the following three requirements were identified as significant risk factors:

- With a rating value of 0.360 or above (Sun, Fang, Wang, Dai, and Ly, 2008; Zhu, 2007);
- With 0.6 or above for the level of frequency of risk occurrence (since the rating is 1-5, Point 3 is considered the neutral point);
- With 0.6 or above for the significance of risk impact (since the rating is 1-5, Point 3 is considered the neutral point).

In order to analyse the significance of factors, the risk factors in each category were filtered by applying the rating value with some factors being excluded which obtained less than 0.360 as the rating value. Table 2 presents the significant risk factors in each category.

Table 2: Ranking of Risk Factors by Significance Levels

Risk Factors	Occurrence RII	Impact RII	Rating Value	Rank	Overall Rank
Financial Risk					
Cash flows	0.856	0.844	0.722	1	1
Capital supply	0.806	0.867	0.698	2	2
Increasing competition	0.739	0.822	0.608	3	6
Legal Risk					
Occupational health/ safety	0.789	0.700	0.552	1	9
Change in law	0.617	0.744	0.459	2	15
Technical Risk					
Equipment availability	0.806	0.794	0.640	1	3
Material availability	0.817	0.772	0.631	2	4
Estimation errors	0.733	0.772	0.566	3	8
Collisions and accidents	0.739	0.706	0.521	4	11
New construction technology	0.689	0.728	0.501	5	12
Design failure/ changes	0.628	0.650	0.408	6	16
Political Risk					
Demand of bribe by politician	0.728	0.683	0.497	1	13
Change of government policy	0.694	0.706	0.490	2	14
Regulations	0.533	0.650	0.347	3	20
Managerial Risk					
Shortage of labour	0.822	0.744	0.612	1	5
Lack of managerial skills	0.744	0.761	0.567	2	7
Less professional involvement	0.728	0.722	0.526	3	10

4.2. RISK ALLOCATION

Using the results, the RII for the allocation of each risk factor was calculated in order to find the percentage of allocation to contractor and client on the basis of which a determination was made whether the risk is allotted to the contractor or client. Table 2 displays the percentage of allocation of each risk factor to the two parties in small-scale construction contracts and the importance of proper risk allocation for the contractor and client/ consultant. However, as risk cannot be handled by one party in some instances, risk responsibility is sometimes shared by both parties. The general principle is that risk is allocated to the party that can handle it or the party that has control over it. According to experts, risk is allocated to the afore-mentioned two parties as seen in Table 2.

4.3. *RISK RESPONSE*

The appropriate risk response measures for significant risk factors in each category were identified through the questionnaire survey in which respondents were requested to point out the appropriate response methods for each risk factor based on their knowledge and experience in the industry. The response measures, which were identified through the preliminary survey, were ranked according to the percentage of usage of those measures in small-scale construction projects as shown in Table 2.

4.4. *PROPOSED RISK HANDLING FRAMEWORK*

Having identified the risk factors, the risk allocation and the handling of such risks in small-scale construction projects, a risk management framework was developed as demonstrated in Table 4. In developing this framework, the risk factors were categorised into six groups initially, the factors being adopted from both the literature review and actual data collection from industry from interviews with industry professionals. Table 3 presents the barrier codes and solutions codes used for the Frame work.

Table 3: Model on Barriers and Solutions to Risk Management

Barrier Code	Barriers to Risk Management	Solution Code	Solutions to Risk Management
B1	Lack of joint risk management mechanisms by parties	**S1**	Hiring risk management consultants
B2	Lack of formal risk management system	**S2**	Recruiting a specialist
B3	Additional cost for risk management	**S3**	Developing a suitable risk management system
B4	No proper mechanism	**S4**	Maintaining proper record-keeping system
B5	Inadequate knowledge/techniques on risk management	**S5**	Education and training regarding techniques on risk management
B6	Ineffective implementation of risk control strategies	**S6**	Developing communication skills
B7	Ineffective monitoring		
B8	Lack of qualified professionals		

Table 4: Risk Handling Framework for Small-scale Contractors

Risk Factors	Allocation		Response Measures	Barriers	Solutions
	Client	Contractor			
Significant Financial Risks					
Cash flows	40%	60%	1. Pre-contract negotiations as to which party will bear which risks	B1, B2. B3, B4	S1, S2, S3
			2. Claiming for damages	B5, B6, B7	S1, S2, S4
			3. Expert judgment	B7, B8	S2
Capital Supply	64%	36%	1. Pre-contract negotiations as to which party will shoulder which risks	B1, B2. B3, B4	S1, S2, S3
			2. Transferring risk to insurance company	B3, B4, B7	S1, S2, S5
			3. Allocation of contingency plan	B1, B2. B3, B4	S2, S5
Increasing Competition	31%	69%	1. Education and training	B5, B8	S5
			2. Expert judgment	B7, B8	S2
Significant Political Risks					
Demand of commission or bribe by Politician	46%	54%	1. Pre-contract negotiations as to which party bears which risks	B1, B2. B3, B4	S1, S2, S3
			2. Teamwork culture	B4, B7	S5, S6
Change in Government Policy	55%	45%	1. Education and training	B5, B8	S5
			2. Expert opinion	B7, B8	S2
Significant Technical Risk					
Equipment Availability	38%	62%	1. Pre-contract negotiations as to which party bears which risks	B1, B2, B3, B4	S1, S2, S3
			2. Allocation of contingency plan	B2, B4, B5	S2, S5
			3. Education and training	B5, B8	S5
Material Availability	40%	60%	1. Pre-contract negotiations as to which party bears which risks	B1, B2, B3, B4	S1, S2, S3
			2. Allocation of contingency plan	B2, B4, B5	S2, S5
			3. Education and Training	B5, B8	S5
Estimation Errors	44%	56%	1. Pre-contract negotiations as to which party bears which risks	B1, B2. B3, B4	S1, S2, S3
			2. Transferring risk to insurance company	B3, B4, B7	S1, S2, S5
			3. Claiming for damages	B5, B6, B7	S1, S2, S4
			4. Brainstorming to identify new risks	B3, B5	S3, S6
Collisions and Accidents	42%	58%	1. Transferring risk to insurance company	B3, B4, B7	S1, S2, S5
			2. Claiming for damages	B5, B6, B7	S1, S2, S4

Risk Factors	Allocation		Response Measures	Barriers	Solutions
	Client	Contractor			
			3. Allocation of contingency plan	B2, B5	S2, S5
New Construction Technology	35%	65%	1. Allocation of contingency plan	B1, B2. B3, B4	S2, S5
			2. Education and Training	B5, B8	S5
Risk Factors	**Allocation**		**Response Measures**	**Barriers**	**Solutions**
	Client	**Contractor**			
Design Failure/ Changes	55%	45%	1. Pre-contract negotiations as to which party bears which risks	B1, B2, B3, B4	S1, S2, S3
			2. Transferring risk to insurance company	B3, B4, B7	S1, S2, S5
			3. Claiming for damages	B5, B6, B7	S1, S2, S4
			Significant Managerial Risk		
Shortage of Labour	30%	70%	1. Education and Training	B5, B8	S5
			2. Brainstorming to identify new risks	B3, B5	S3, S6
			3. Team work culture	B4, B7	S5, S6
Lack of Managerial Skills	34%	66%	1. Education and Training	B5, B8	S5
			2. Team work culture	B4, B7	S5, S6
Less Professional Involvement	39%	61%	1. Education and Training	B5, B8	S5
			2. Team work culture	B4, B7	S5, S6
			Significant Legal Risk		
Occupational Health/ Safety.	44%	56%	1. Education and training	B5, B8	S5
			2. Physical protection to reduce the likelihood of risk	B3, B7	S5, S6
			3. Physical protection for people and property	B3, B7	S1, S5
Change in Law	56%	44%	1. Pre-contract negotiations as to which party bears which risk	B1, B3, B4	S1, S2, S3
			2. Allocation of contingency plan	B2, B3, B5	S2, S5
			3. Education and training	B5, B8	S5
			4. Expert judgment	B7, B8	S2

In this framework (refer Table 4), the first column represents the most significant risk factors in each category while the second column deals with the percentage of allocation of identified risk factors to the two parties in the contract. The appropriate response measures to small-scale construction risks are shown in the third column while the last two columns specify the barriers with regard to the implementation of response measures in the risk management process and the possible solutions to overcome those barriers.

The framework shows that small-scale construction projects consistently face the afore-mentioned risks at different stages of the project. Since all identified risk factors cannot be eliminated completely, it would be better to be remaining alert to the occurrence of such risks and their impacts on the projects via reference to this framework. The framework further reveals the allocation, response measures, barriers and solutions with regard to risk factors that small-scale contractors should have a proper understanding of. However, it is best that both parties to the contract handle the identified risks by showing proper concern towards them despite challenges in the way of risk management in small-scale construction projects. The percentage amount of allocation of each risk factor to each of the two parties is given in detail in this framework. It shows that it is wiser in small-scale construction industry for the party that can control the risk to take responsibility for it rather than passing the risk to the other party. The framework contains the appropriate response measures for the identified risk factors which clearly demonstrate ways to mitigate each risk as soon as it is encountered in the field. Further, the barriers listed make it possible for those in the small-scale sectors to identify them early so as to properly plan for them in advance and thus mitigate the stress associated when obstacles appear of a sudden. The framework further offers solutions to overcome the barriers identified with regard to each risk factor in detail which gives proper guidance in risk management to parties in the field of small-scale construction.

5. CONCLUSIONS

The ccompletion of a construction project within the allocated budget, time and required quality is becoming a major concern due to the cost overruns, time delays and poor quality of countless projects in Sri Lanka. The completion of small-scale construction projects is additionally affected by financial, legal, technical, political, managerial and communication risk factors that are peculiar to them. Therefore, a critical understanding of risk management has become of vital importance for Sri Lankan small-scale contractors. With the objective to identify and classify the risk factors associated with small-scale construction projects and to see how they are handled by the contracting parties, in mind, the study initially identified the significant risks in small-scale construction. Having evaluated the allocation of significant risk factors to each risk category, they were analysed in order to determine which of the two contracting parties involved in small-scale construction projects should bear a particular risk. The study further derived the available risk response techniques for the above significant risk factors. In addition, it identified the barriers in the way of implementing the response measures as well as the solutions to overcoming those barriers as proposed in the Table 5. The accomplishment of the ultimate objective of this research, which was to provide a framework of risk management for small-scale contractors in building projects in Sri Lanka, was possible based on the findings of the questionnaire survey and literature survey. The framework specified that the sharing responsibilities among the parties involved in a construction project is necessary as assigning overall responsibility to one party carries some element of danger and would incur more cost should the perceived risky situation were to occur. Hence, it is customary to shift the responsibility for the risk to either the contractor or the client and sometimes to share it among both parties.

6. RECOMMENDATIONS

The findings of this research deserve attention because they highlight the different types of risks that small-scale construction projects consistently face in different stages of the project. Small-scale construction projects are affected by several critical and severe risk factors, which are both unforeseeable as well as unavoidable by the parties contracted under the project. However, risk management in small-scale construction projects is crucial for completion of the projects within the allocated budget, time and required quality. Since risk factors cannot be eliminated completely, it would be better to minimise their occurrence and their impact on the project objectives by adopting proper response measures from the inception of the project with better interaction among the contracting parties

There is no doubt that risks directly affect the construction process leading to both delays and cost increases for both clients and contractors. Hence, it is a good practice for both parties to show concern for and handle risk despite the challenges posed for risk management in small-scale construction. Further, it is best for all concerned in the small-scale construction industry for the party that is better able to control to bear it rather than passing it onto the other party. The researchers further recommend that the framework developed in the present study be utilised at the initial stages of the project since it includes the significant risks, their allocation to the contracting parties, the response measures that could be implemented to deal with the risk factors, the barriers in the way of such implementation and solutions to overcome the perceived barriers. The framework is clear and is prepared in a manner that makes it discernible at a glance by small-scale contractors. Further, the framework guides small-scale contractors to being vigilant about risks that may overlap in the course of the project cycle. Risks are inherent and unavoidable in the construction industry and small-scale contractors must learn to work with these risks that are spread throughout the project life-cycle. In conclusion, it can be recommended that small-scale contractors should map the prevailing risks associated with their work even as they resort to the proposed framework for the identification and management of risk in small-scale construction industry.

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RECENT DEVELOPMENT OF VERTICAL AXIS WIND TURBINE: A PROMISING SOLUTION

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ABSTRACT

There is crucial need for clean and sustainable energy supplies nowadays. In recent years, wind energy is considered one of the most promising energy sources. Horizontal Axis Wind Turbines (HAWT) has been the widely practiced type, whereas Vertical Axis Wind Turbines (VAWT) is the lesser known type. To harvest wind energy at higher height, tremendous advancements have been progressed in the wind turbine technology with boosted size and capacity, as well as lighter components to achieve cost effectiveness and technical efficiency. Some of the recent findings revealed the potential of VAWT in future development. This paper aims to describe the recent development of VAWT and its merit over the conventional HAWT. The reasons driving the market to investigate the feasibility of using VAWT again are discussed, as well as the limitation of its future development. Finally, the feasibility of using VAWT in future wind power industry is evaluated. It is concluded that VAWT has significant development potential in future market of producing efficiency wind energy.

Keywords: *Aerodynamics; HAWT; Structural Dynamics; VAWT; Wind Engineering; Wind Power*.

1. INTRODUCTION

Wind Energy is considered one of the most promising energy sources (Islam *et al.*, 2013). Over the past decades, research studies of Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT) have been focusing on to maximise wind power output (Islam *et al.*, 2013). Figure 1 shows the typical configurations of HAWT and VAWT. Tremendous advancements have been progressed in the wind turbine technology in recent years with boosted size and capacity, as well as lighter components to achieve cost effectiveness and technical efficiency (Harte *et al.*, 2012). As such, it is worthwhile to compare the development of both systems in recent years and to evaluate the possible reasons driving the market to favour HAWT.

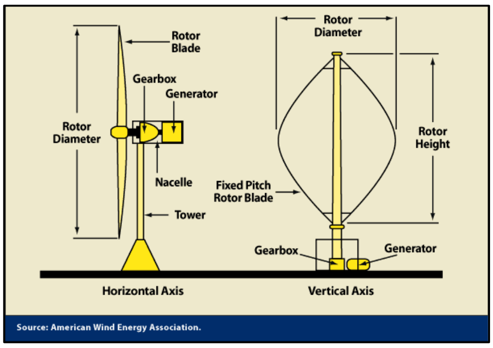

Figure 1: Wind Turbine Configuration
Source: American Wing Energy Association

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2. BACKGROUND

It is understood that Wind has been used as energy source long time ago. (Eriksson *et al.*, 2008). Approximately 900AD, the first windmills were used by Persians while this is in the form of VAWT. Then, both HAWT and VAWT have been developed and during 20th Century, HAWTs continued to develop where larger modern HAWTs were constructed (Islam *et al.*, 2013).

Today, the most common wind turbine is HAWT. By definition, the axis of rotation is along to the ground which is considered to be the horizontal axis. Basic rotation concept is presented in Figure 2a and 2b.

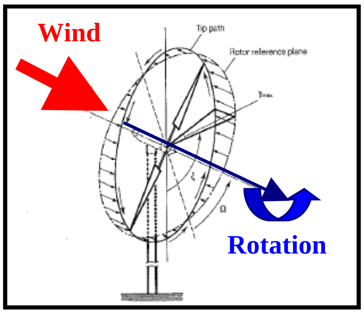

Figure 2a: HAWT Schematic Drg. 1

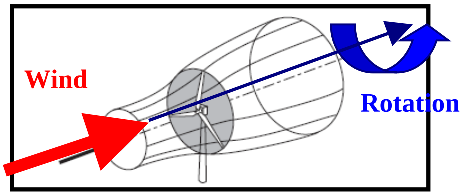

Figure 2b: HAWT Schematic Drg. 2
Source: Freris (1990)

Contrary to HAWT, Vertical Axis Wind Turbines (VAWT) is the axis of rotation to be along to the vertical axis. See below Figure 3a and 3b.

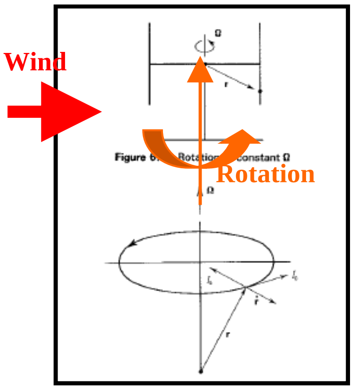

Figure 3a: VAWT Schematic Drg. 1 - Section

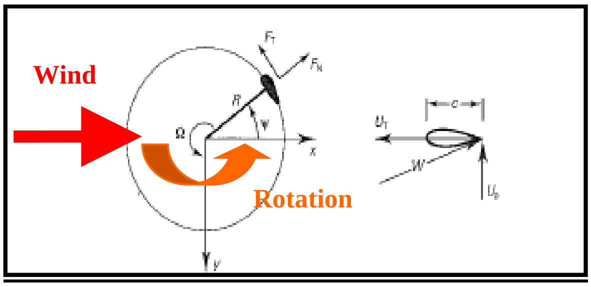

Figure 3b: VAWT Schematic Drg. 2 - Plan
Source: Freris (1990)

Under the category of VAWT, there are three different concepts, namely: Savonius Turbine, Darrieus Turbine and the H-Rotor. Refer Figure 4.

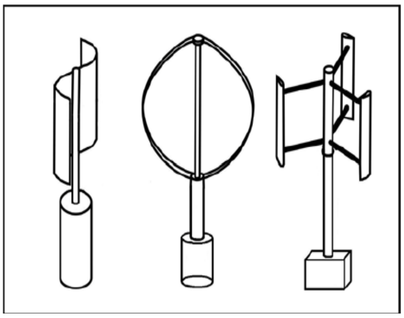

Figure 4:- Basic VAWT Configurations. Savonius Rotor (Left), Darrieus Rotor (Middle) and H-rotor (Right). In 1922, S.J. Savonius invented Savonius rotor where George Darrieus patented his Darrieus rotor in 1931. H-rotor is a form of Darrius type with straight blades instead of curve blades.
Source: Eriksson *et al.* (2008)

Basic wind power equation (1) is as follows:-

$$\text{Power (P)} = 0.5 \times Cp \times \rho_{air} \times A \times V^3 \qquad \text{(Eq: 01)}$$

where, ρ_{air} = Density of Air, Cp =Turbine efficiency, A = Swept Area (Wind projected area covered by the wind blade swept), V = Wind Velocity.

A power law profile (boundary layer) is used as an arithmetical approximation for wind velocity against height. Refer Figure 5.

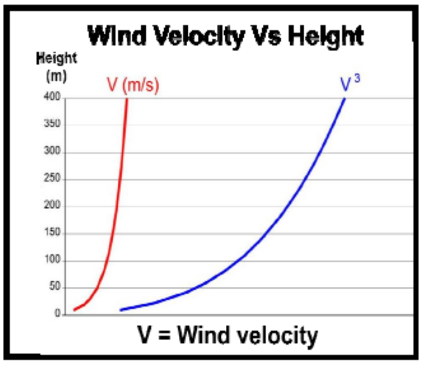

Figure 5: Wind Velocity (V and V^3) Against Height According to Boundary Condition

From Eq: 01, we can reveal that the wind power generation (P) is directly proportional to Cp, A and V^3 if we consider ρ_{air} is around 1.22kg/m^3.

Different type of wind turbines will have different value of Cp. According to Betz Limit (Freris, 1990), the maximum Cp value is 0.593 where this is the energy can be obtained from wind turbine under idealised condition. A more detail explanation of different Cp value for HAWT and VAWT will be discussed in later section.

On the other hand, if a wind turbine can provide a larger value for A and V^3, wind energy generation (P) can be higher. This is the reason why both HAWT and VAWT are aimed to be larger and higher in their development.

3. AIMS AND OBJECTIVES

This paper aims to describe the recent development of VAWT and its merit over the conventional HAWT. The reasons driving the market to investigate the feasibility of using VAWT again are discussed, as well as the limitation of its future development. Finally, the feasibility of using VAWT in future wind power industry is evaluated.

Objectives of this paper are as follows:-

- Identify advantages and disadvantages of HAWT and VAWT
- Evaluate the key reasons why HAWT is more common in the market
- Identify current obstacle of HAWT and limitation in future development
- Evaluate feasibility of VAWT in future development, particular those large scale wind turbines which is higher and larger in size.

The information of design data of recent HAWT and VAWT will be collected. They will be quantified for analysis to identify the advantages and disadvantages of each type of wind turbine. Key reasons driven the market towards HAWT will be evaluated and identification of current design obstacles of HAWT for further development. Potential of VAWT in future development will be discussed and finally, it is purposed to obtain conclusion that VAWT will be a promising solution in wind power industry to capture higher energy with higher height and swept area.

4. METHODOLOGY

There are several elements involved in the design and construction process for HAWT or VAWT whereas it is necessary to understand. To illustrate their relationship, an IDEF (0) model shown in Figure 7 is used.

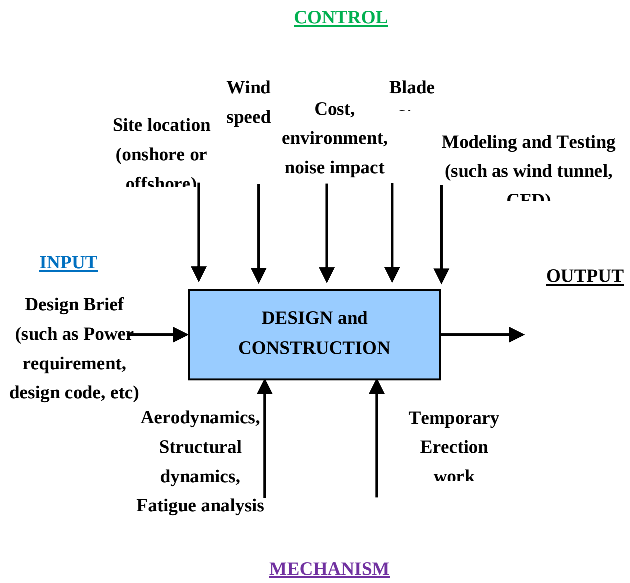

Figure 7: IDEF (0) Model

The process shown in IDEF (0) model is illustrated by a rectangular process (design and construction) that produces outputs from inputs where various mechanisms with difference controls.

However, in order to have more detailed description of the process, IDEF (1) model is demonstrated below (refer Figure 8) to show the relationship with Design and Construction as separate process.

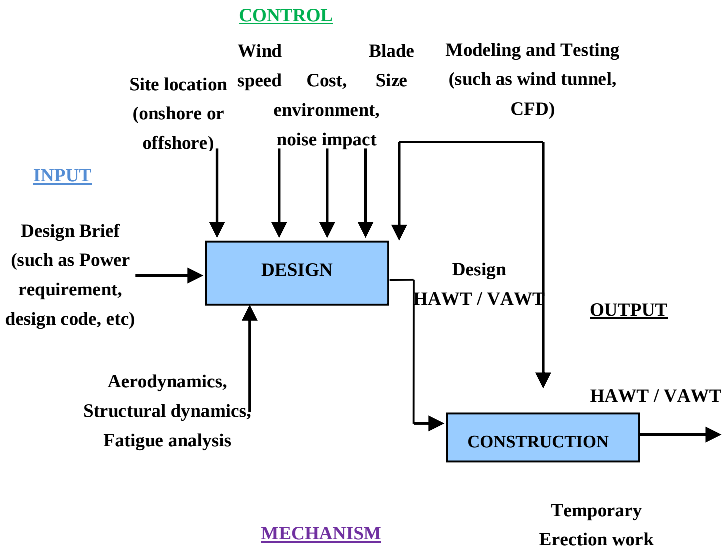

Figure 8: IDEF (1) Model

In the above IDEF (1) model, it is considered that the design and construction process are linked by a control – modelling and testing.

With the above understanding for process of HAWT and VAWT's design and construction and in order to answer research questions, the following work tasks are required;

- Literature review on relevant documents on the basic design principle of HAWT and VAWT. During this stage, key consideration in the field of aerodynamics, structural mechanics and dynamics and fatigue analysis of HAWT and VAWT are identified.
- Collection of data from published journal papers of the recent as-built HAWT and VAWT. These data can provide information on the consideration in terms of cost, environment and noise issue as well as the difficulties during temporary erection work.
- Analyse the information gathered to identify findings corresponding to research objective.

5. Literature Review

5.1. Recent Development of HAWT and VAWT

After oil crisis in 1973, many countries commenced their development programs for wind energy projects and to look for reliable renewable energy source in lieu of the conventional fossil fuel. In 1975, a 38m diameter two blades HAWT with rated power output of 100kW was constructed near Cleveland, Ohio of the United States. Subsequently, during 1970s to 1980s, a numbers of different multi-megawatt wind turbines (both HAWT and VAWT) were constructed and completed (Kirke, 1998).

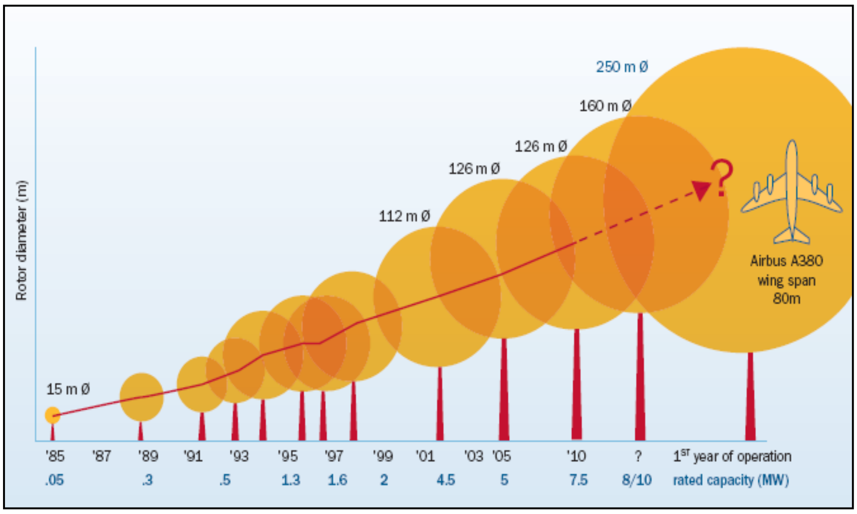

Figure 9: Recent HAWT Rotor Size
Source: http://1.bp.blogspot.com/-sr7ynn7H6Qo/T-H-d0nI8XI/AAAAAAAAAVtk/1hBcaNRv5hQ/s1600/wind20mwb.png

In 2007, the tallest HAWT (Enercon E-126) was built with height of 198m and blade diameter of 126m which can generate electricity up to 7 Megawatt (7MW). From published data, it is understood that study of producing blade length up to 100m long for HAWT has been carried out in the Sandia National Laboratories of the United States (Veers, 1984).

Figure 10: Enercon E-126

Several prototypes of VAWTs in the form of Darrieus were initiated by both Canada and the United States. The Eole, the tallest Darrieus VAWT was built in 1986 in Quebec of Canada (refer Figure 11). It can produce rated power output up to 4MW (Templin and Ranj, 1983).

Figure 11: The Eole, VAWT in Quebec of Canada

The Eole was operated until in 1993 due to a report of failure of the bottom bearing. On the other hand, in Sandia National Laboratories of the United States (refer Figure 12), numbers of different size of Darrieus VAWT were operated until in 1997, the last VAWT was shut down due to the problem observed in its foundation. Some others VAWT also reported to have fatigue problems of the blades even though the VAWT was operated efficiently (Berg, 1985).

Figure 12: VAWT in Sandia National Laboratories

In the 1980s, American company FloWind constructed a wind farm in the United States by using VAWT of Darrieus form (refer Figure 13).

Figure 13: Wind Farm under FloWind

In 1980s to 1990s, in the United Kingdom, H-rotor type was investigated and a 500kW VAWT H rotor was built in 1989 (refer Figure 14).

Figure 14: VAWT (H Rotor) in UK

Based on published information, in the 1980s, due to a poor wind energy market in USA, numbers of VAWTs' company were required to close and the development of VAWT was slow down thereafter.

It is clear that both HAWT and VAWT are developed in parallel initially while after few reported case of VAWTs' problem and less financial support and interest from investors, HAWTs received more attention and nowadays, most of the large wind turbines are in the HAWT form.

Eriksson *et al.* (2008) summarise of the differences between HAWT and VAWT is tabulated in Table 1.

Table 1: Summary of Main Difference between HAWT and VAWT

	HAWT	**VAWT (Darrieus)**	**VAWT (H- rotor)**
Blade profile	Complicated	Complicated	Simple
Yaw mechanism	Yes	No	No
Pitch mechanism	Yes	No	Yes
Central tower	Yes	No	Yes
Guy wires	No	Yes	Optional
Noise	High	Moderate	Low
Blade area	Small	Large	Moderate
Generator position	On top of tower	On ground	On ground
Blade load	High	Low	Moderate
Self -starting	Yes	No	Yes/No
Tower interference	Large	Small	Small
Foundation complexity	Extensive	Simple	Moderate
Overall structure complexity	Complicated	Simple	Simple

Source: Eriksson *et al.* (2008)

5.2. *AERODYNAMICS*

Based on Eq: 01 discussed in previous section, it is understood that the wind power generated (P) is directly proportional to the Cp value which is the turbine efficiency. This Cp value is the interaction relationship between the rotor and the wind. According to Betz Law (Freris, 1990), the maximum Cp value for an idealised wind turbine is 0.59. Different Cp value for HAWT and VAWT are shown in the following Figure 15.

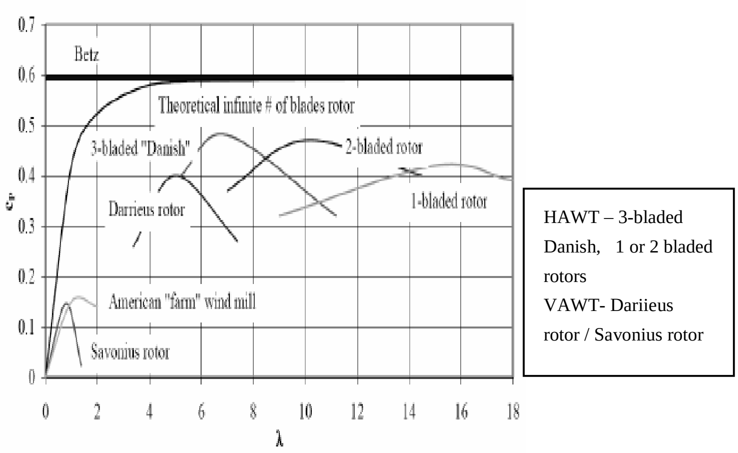

Figure 15: Cp –λ Curve for HAWT and VAWT
Source: Kirke (1998)

Cp is a function of the tip speed ratio λ which is defined as $\lambda = \omega R / \upsilon$ where ω is turbine rotational frequency, R is turbine radius and υ is wind speed.

For a HAWT, the CP value is usually between 0.40 and 0.50 while generally, VAWT's CP value is lower than HAWT.

However, recent study has revealed that VAWT's Cp value can be increased and to be close to HAWT (Hunter, 2009). It is considered one of the main breakthroughs in recent development of VAWT.

5.3. STRUCTURAL MECHANICS AND DYNAMICS AND FATIGUE

It is evident that major aspects of wind turbine performance are determined by the aerodynamic forces generated by the wind. These periodic aerodynamic forces are the source of fatigue load which affect the structural performance of both HAWT and VAWT. Wind turbines use airfoils to transform kinetic energy in the wind into useful energy. Airfoils are structures with specific geometric shape that used to generate mechanical force due to the relative motion of the airfoil and the surrounding air (Zhang, 2004). A typical airfoil shape for a blade is shown as follow Figure 16.

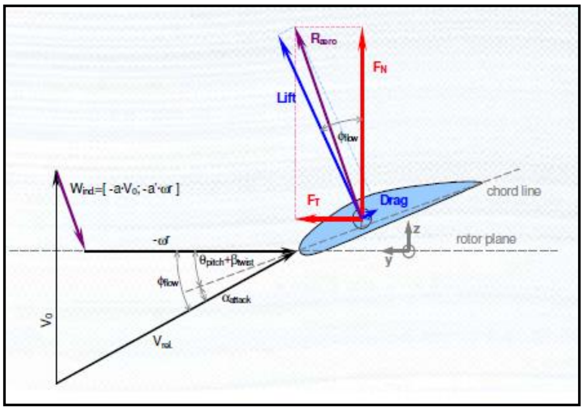

Figure 16: Typical Airfoil Shape of Wind Blade Showing the Lift and Drag Force
Source: Freris (1990)

5.3.1. HAWT

The blade of a HAWT is subjected to reversing aerodynamic forces at its root during its rotation along the horizontal axis in Figure 17. With this periodical loads act on the blade, the blade is considered susceptible to fatigue problem (Eriksson *et al.*, 2008). With the advances of today's material mechanics, nowadays, in lieu of using aluminium, these blades are made of composite material including carbon fiber or glass fiber. It is considered that the problem of fatigue in blades is reasonable managed in current HAWT. However, as size of blades increases substantially in the recent development, fatigue problem is still considered one of the major design constraints in HAWT.

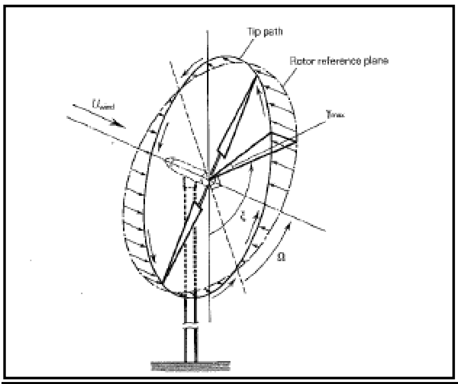

Figure 17: HAWT Showing Reversing Aerodynamic Forces at its Root during Rotation
Source: Freris (1990)

Apart from blade's aerodynamic forces and fatigue problem, HAWT is subject to tower interference and resonance problem during its operation (Eriksson *et al.,* 2008). Tower interference will eventually affect the performance of the turbines. However, for VAWT, the tower interference is considered less significant as the blades are located far away from the central tower.

Resonance will cause significant vibration and problem on the main tower and foundation, which is also the case for VAWT.

5.3.2. VAWT

Unlike the case of HAWT, VAWT's blade is not subject to a gravity induced reversing stress. However, VAWT is subjected to inherent torque ripple where this is caused by the changing of angle of attack between the blades and the incoming wind during the rotation along vertical axis. This torque ripple can affect the fatigue life of the drive train components and power output quality. On the other hand, the changing of angle of attack during each rotation will cause cyclic aerodynamic forces on the blades. Again, fatigue become a key issue to address during both design and construction stage of VAWT. Nevertheless, as mentioned before, with the advances of current material science by using carbon fiber to fabricate wind blades, fatigue issue can be reasonably controlled (Eriksson *et al.,* 2008).

5.4. CONSTRUCTION AND BLADE MANUFACTURE

Both HAWT and VAWT require a specific design of temporary erection procedures for the installation of blades. Blades of HAWT are attached directly to the central tower while blades of VAWT (H-rotor) are connected with central tower by a supporting arm. The supporting arms will add extra loading on the tower structure (Eriksson *et al.,* 2008).

The blades of HAWT require different shape along the length of the blade where it might be needed to be twisted under some circumstances. For VAWT (H-rotor), the blade can have same shape along the length so that the manufacturing process will be easier (Eriksson *et al.*, 2008).

5.5. NOISE IMPACT

VAWT is expected to have less noise than VAWT. This is due to the fact that a VAWT usually has tip speed ratio which is only half of the tip speed ratio of HAWT. As a result, there will be less aerodynamic noise.

6. ANALYSIS AND DISCUSSIONS

The followings are the research questions to be addressed in this paper.

- What are the advantages and disadvantages of HAWT and VAWT respectively?
- Why HAWT is the majority type of wind power in market in the past few decades?
- Has HAWT reached its design limit?
- Does VAWT demonstrate potential for future development?

The advantages and disadvantages of HAWT and VAWT can be summarised as follows.

HAWT's Advantages

- High turbine efficiency Cp value than current VAWT.
- Well established understanding and study on system performance, both in design and construction prospective.
- Adequate financial support due to more reliable system which has been proven.

HAWT's Disadvantages

- Blades approaching limit of viability as size increase.

- Yaw mechanism need. High cost required.
- Increase cost to handle fatigue problem as blade size becomes longer and larger.
- Higher noise level

VAWT's Advantages

- Wind from all direction can be captured and no yaw mechanism need.
- Simple blade airfoil shape design. Blades still have design capacity to cater for larger size VAWT.
- Less noise than HAWT.

VAWT's Disadvantages

- Low Cp value as compared to HAWT. However, some researchers claim that this may not be necessary true for modern VAWT.
- Self-starting problem as compared with HAWT. That means VAWT will not be able to start rotating. However, Kirke (1998) reported a type of VAWT can be self-starting and recent study also demonstrates it may not be necessary true and only happen under certain category.
- Inadequate understanding and study on system performance, both in design and construction prospective. Further study need to justify.
- Inadequate financial support due to lack of confident of system performance. Previous failure cases cause investor's hesitation to develop VAWT.

It is no doubt that in current markets, HAWT dominate the wind power industry. This is highly due to the fact that HAWT has shown a promising result over the last few decades where people do not have motivation to look for other solution. Also, HAWT tends to be more reliable due to the lesser problems as compared to VAWT. Therefore, more investment has been put into development of HAWT. In view of the technical consideration, both HAWT and VAWT has demonstrates their competence to harvest wind energy.

It is revealed that fatigue problem of blades of HAWT under the periodic aerodynamic forces with reversing stress acting on the root of the blades, will lead to the main limitation for increasing size for HAWTs. (Eriksson *et al.*, 2008)

Also, from Figure 9 showing HAWT's recent development from 1980s, it can observe that development of larger HAWT has been slow down recently. It reveals that it is due to difficulty to climb over the current height limit by HAWT. It is one of the main reasons why driven the researchers to go into VAWT again.

7. EVALUATION FOR THE FEASIBILITY OF VAWT IN FUTURE DEVELOPMENT

The technical advancement of VAWT lags behind that of the HAWT despite of the advantages of VAWT in terms of aerodynamic and efficiency. Nevertheless, stochastic nature of wind (e.g. changing its speed and direction) makes HAWT not favourable as compared with VAWT which do not need any unidirectional wind speed and no yawing mechanism is required. VAWT demonstrates that it is more effective in large scale development for harassing wind energy.

Islam *et al.* (2013) summarised that though the HAWT is well developed and adopted in the existing wind power industry, the recent R&D has shown that VAWT is more economical and efficient in respect to the required land use. In general, it is proved that using VAWT instead of HAWT on the same land area, it is likely to produce more than 10 times of wind energy. That means the power density of VAWT is considered substantially higher than that of the HAWT. These research findings were presented by Whittlesey *et al.* (2010). As such, with a same land area, it is feasible to produce more energy by using VAWT instead of HAWT. That will become one of the crucial considerations for future development of wind farm with VAWT.

Based on current research study on VAWT, it is proven that VAWT is a good solution in wind power industry due to its advantages to capture wind energy from all directions, as well as the recent advances in turbine efficiency Cp value for VAWT and more effective design of blades. It is understood that a multi-megawatts VAWT in UK's offshore area is about to construct (Hunter, 2009). Potential of VAWT in future development is considered promising.

8. CONCLUSIONS AND SUGGESTIONS

This paper presents a review on the recent development of HAWT and VAWT. Publications in major journals, books and research thesis revealed that both HAWT and VAWT have advantages and disadvantages. Basically, HAWT has been popular due to its higher Cp value, its reliable system performance owing to its well-established understanding and supporting research findings, and financial support and interest from investors, despite that some of the drawbacks like blade approaching limits of viability, high noise level and high cost to overcome fatigue problem.

On the other hand, VAWT is considered to have lesser attention due to several failure cases in 1980s to 1990s, as well as the shutdown of some VAWT's company, which eventually directed more focus and investment on HAWT in the past decades. VAWT has inevitably advantages in terms of its simplicity in blade airfoil shape and the ability to capture wind from all direction without the use of yaw mechanism. Recent advances in turbine efficiency Cp for VAWT has driven the market to investigate the feasibility of using VAWT in wind energy industry again. Moreover, recent research has demonstrated that higher power density of VAWT in respect to a given land area is also promising. It is expected that commercialised large scale VAWT will be in operation in the near future.

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RELATIONAL CONTRACTING APPROACH FOR IMPROVING PERFORMANCE OF INFRASTRUCTURE DEVELOPMENT PROJECTS

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ABSTRACT

Relational Contracting (RC) is a flexible procurement approach directed at optimising project performance through applying its principles; aiming at the relational integration of all stakeholders of a project, by engaging them in "cross linked value networks". Partnering, alliance, private-public partnerships and joint ventures are the common procurement types of such nature. Although RC have proven benefits especially for complex and uncertain infrastructure development projects, these are not well established in most developing countries including Sri Lanka. Therefore, understanding of industry practitioners on how RC systems bring in performance improvements to construction projects will definitely promote RC. In view of that, the research aims to provide related knowledge by identifying and subsequently assessing the impact of key parameters of RC on major performance areas of infrastructure development projects. A questionnaire survey was conducted based on the knowledge gained through literature and was followed by an interview survey to validate the questionnaire survey findings derived through statistical t-tests. Questionnaire findings identified nineteen significantly existent characteristics in RC types and were recognised as highly important for 'Time', 'Cost' and 'Quality' performance of infrastructure development projects. Thus, adopting of RC should be promoted to achieve better project outcome.

Keywords: *Construction Performance; Infrastructure Development Projects; Procurement Methods; Relational Contracting.*

1. INTRODUCTION

The construction industry is one of the key activities in any country's economy while physical infrastructure is a major construction industry segment. Hence, enhanced performance of infrastructure projects is of paramount important for a country to achieve national development.

Performance of construction projects is considerably affected by procurement practices as well as contracting structures and styles (Palaneeswaran *et al*., 2003). For instance, poor performance is more evident in traditional adversarial type of contracts (Enshassi *et al.*, 2009); conversely, construction project performance in whole range of criteria can be dramatically improved if collaborative working practices are incorporated in to the project environment (Bennett and Jayes 1995 cited Bresnen and Marshall 2000b p. 229). Relational Contracting (RC) is one of the approaches capable of inducing such changes (Rahman *et al.*, 2007).

Relational Contracting (RC) is a set of principles or a philosophy of contracting when its elements are incorporated into a contract, referred as a relational contract (Mclennan, 2000; Yeung *et al.*, 2012). Further, RC replaces legal provisions with informal agreements (Rahman and Kumaraswamy, 2002) and considers contracts to be ongoing dynamic (flexible) and long term 'relationships' between parties (Macneil 1980 cited Chang *et al*., 2010 p.04). RC gives rise to a spectrum of project delivery systems with different combinations of relational elements at different degrees. Among them, partnering, joint venture, alliancing and public private partnership are commonly used RC systems.

Partnering is of two types namely project partnering and strategic partnering where project partnering refers to one off scheme and strategic partnering refers to on-going schemes over a series of development (Bennett and Jayes, 1995). Alliancing too has two categories namely strategic alliancing and project alliancing (Rowlinson and Cheung, 2002). The key difference between project partnering and project alliance is that partnering do not has a contractual enforceability itself and merely based on relational aspects whereas

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alliances have (Manley, 2002). Joint Venture (JV) is a relational strategy used by companies to temporarily combine finance, skills and knowledge and other resources (Walker and Johannes, 2003). Public Private Partnership (PPP) is a long-term contractual agreement between a public sector body and a private sector entity, where private sector entity is entitled to construct or manage a public sector infrastructure facility or provide services to the public using that facility on behalf of the public sector (Grimsey and Lewis, 2002). Among them JV is the widespread RC system in Sri Lankan industry. However, these systems are not perfectly established in Sri Lanka, instead they only incorporate the RC attributes to a limited level.

The primary objective of this paper is to affirm on value of RC approach, by exploring how RC systems contribute to improve performance of infrastructure construction projects. For that purpose, this research identifies the key parameters in RC systems for enhancing construction performance and subsequently assesses the impact of them to improve the performance of infrastructure development projects.

2. RESEARCH METHODOLOGY

2.1. INITIAL SURVEY

Key characteristics of RC systems, which have capacity to enhance performance of construction projects, were identified through an extensive literature survey. Having prepared the draft questionnaire based on the literature findings, a pilot survey was conducted by interviewing an academic expert and an industry expert to elicit their knowledge with view to identify any further characteristics which is more or less unique to the local industry practices. No new characteristic of RC were found through this expert survey however the questionnaire was improved with their comments. As the next step, industry-wide questionnaire survey was carried out to identify significant characteristics contributing to infrastructure development project performance in the practical scenario in Sri Lankan construction industry.

2.2. QUESTIONNAIRE SURVEY

Sample Selection: Main stakeholder such as clients, consultants, contractors and suppliers in the supply chain of infrastructure projects were considered in the sample population. Contact information of such stakeholders who are involved in large-scale infrastructure development projects was collected to establish the sample framework. It was believed that persons who have more than 10 years of total experience in construction industry and who have been involved both in RC systems and in infrastructure development projects as experts to the research. The contacts were collected from Institute of Construction Training and Development (ICTAD), leading organisations of the sector and from the telephone directory. A sample of 32 number of such persons was selected through Random sampling technique. Among them, 7 persons were from client organisations, 8 from consultants, 10 from contractors and 7 from supplier organisations.

Questionnaire Design: The questionnaire consists of three sections. In the first section, demographic characteristics of the respondents were asked to confirm that the respondents have achieved the criteria concerned in refining experts related to this research. Section two aims at identifying the level at which the RC characteristics exist in RC systems in the Sri Lankan construction industry. This section comprise of single question with twenty-one RC characteristics identified from the initial survey, for the respondents to rate in a seven-point Likert scale (1=Not exist at all, 2= Very weekly exist, 3=weekly exist, 4= Moderately exist, 5=Exist, 6=Strongly exist, 7=Very Strongly exist). The third section aims to identify the respondents' opinion on the importance of the same RC characteristics on improving performance of infrastructure development projects with related to five performance indicators namely, *time, cost, quality, health and safety and environment.* The respondents were asked to rate using a similar seven-point Likert scale (1=Not important at all, 2=Very weekly important, 3=Weekly important, 4=Moderately important, 5= Important, 6= Strongly important, 7=Extremely important).

Survey and analysis: Final questionnaire was delivered by hand as well as through electronic mail after confirming the respondents' accomplishment of the criteria established to identify experts to the research. One sample t-test was adopted to identify RC characteristics that significantly exist in RC systems and to identify RC characteristics, which are significantly important for five performance areas considered separately. Accordingly, null hypothesis was defined as 'H_0: $\mu = \mu_0$' and alternative hypothesis as 'H_1: $\mu \neq \mu_0$', where μ is population mean and μ_0 is the hypothesised value of population mean. In the analysis, μ_0

was positioned at '4' which is the moderate level of existence/importance. T-tests were conducted using 'statistical Package for Social Science (SPSS)' software. The characteristics which had 'significance' less than 0.05 (level of significant used for the test) and positive t value, were considered as significantly existing/ highly important above the moderate level. Following the analysis of questionnaires, four number of unstructured interviews were conducted to extract further expert views with regards to questionnaire survey results.

3. DISCUSSION

3.1. RC CHARACTERISTICS

Among the 21 characteristics tested, 19 were established through t test results as significantly existent in Sri Lankan RC systems. Table 1 shows these significant characteristics.

Table 1: Significant Characteristics in RC Systems

No	Characteristic	Sig	t-value	Rank
C17	Resource sharing	0.000	12.785	01
C08	Continuous effort on performance improvement	0.000	11.633	02
C18	Enthusiasm	0.000	10.001	03
C05	Common/mutual project goals	0.000	09.423	04
C15	Mutual understanding	0.000	08.575	05
C01	Commitment	0.000	08.358	06
C07	Immediate problem resolution at lowest level	0.000	08.358	06
C04	Open and effective communication	0.000	08.042	08
C16	Ethical conduct and discipline	0.000	08.019	09
C11	Integrated team building	0.000	07.996	10
C06	Sharing risks and rewards	0.000	07.830	11
C02	Mutual trust	0.000	07.482	12
C14	Mutual respect	0.000	06.937	13
C03	Cooperativeness and collaboration in relationships	0.000	06.297	14
C12	Long term relationships	0.000	05.822	15
C09	Informal agreements	0.000	04.937	16
C10	Workshops	0.000	04.559	17
C13	Contractual flexibility	0.000	04.360	18
C20	Relational selection	0.003	03.215	19

Further, the characteristics were analysed to identify their importance for improving the performance of infrastructure development projects in terms of *Cost, Time, Quality, Health and safety and Environment*. Traditionally success of construction projects is measured with *time, cost and quality* (A.P.C. Chan and Chan, 2004) while health and safety issues and environmental impact are among other two aspects commonly dealt with infrastructure projects (Eriksson and Westerberg, 2011).

According to the results, all significantly existent 19 characteristics were found significant for overall performance improvement of infrastructure development projects (refer Table 2). Among them, 'C01: Commitment to achieve project targets' is the RC element having highest contribution. Moreover, 'C08: Continuous effort on performance improvements' is the most important characteristic for 'Time' performance. 'C05: Mutual project goals' was identified as the most significant contributor to both 'Cost performance' and 'Environmental performance' while 'C01: Commitment to achieve project targets' is most important for both 'Quality' and 'Health and safety' performance.

Table 2: RC Characteristics and Infrastructure Development Project Performance

No	Significantly Existent Characteristics in RC Systems	Performance Indicators																	
		Time			Cost			Quality			Health and Safety			Environment			Overall		
		Sig (2 tailed)	t-value	Rank	Sig (2 tailed)	t-value	Rank	Sig (2 tailed)	t-value	Rank	Sig (2 tailed)	t-value	Rank	Sig (2 tailed)	t-value	Rank	Sig (2 tailed)	t-value	Rank
C05	Common project goals	0.00	14.20	05	0.00	20.26	01	0.00	13.92	04	0.000	8.82	02	0.000	7.53	01	0.00	15.39	01
C08	Continuous effort on performance improvement	0.00	25.68	01	0.00	18.16	02	0.00	13.11	06	0.000	6.42	05	0.000	4.54	05	0.00	15.31	02
C01	Commitment	0.00	15.87	04	0.00	13.33	04	0.00	14.60	01	0.000	9.19	01	0.000	5.38	04	0.00	14.49	03
C18	Enthusiasm	0.00	16.84	03	0.00	10.52	07	0.00	14.43	02	0.000	8.28	03	0.000	6.29	02	0.00	12.49	04
C10	Workshops	0.00	10.27	11	0.00	9.12	11	0.00	14.09	03	0.000	5.75	07	0.000	4.00	07	0.00	12.27	05
C04	Open and effective communication	0.00	13.12	07	0.00	11.20	06	0.00	13.85	05	0.000	6.56	04	0.003	3.18	11	0.00	12.18	06
C11	Integrated team building	0.00	10.60	10	0.00	7.57	13	0.00	10.00	10	0.000	5.04	08	0.000	4.45	06	0.00	10.32	07
C20	Relational selection	0.00	11.50	08	0.00	9.16	10	0.00	10.80	09	0.000	6.04	06	0.000	5.80	03	0.00	9.91	08
C03	Cooperativeness and collaboration in relationships	0.00	13.26	06	0.00	8.94	12	0.00	11.12	08	0.001	3.54	10	0.010	2.73	12	0.00	9.72	09
C07	Immediate problem resolution at lowest level	0.00	7.60	15	0.00	13.47	03	0.00	8.36	11	0.009	2.80	14				0.00	9.52	10
C15	Mutual understanding	0.00	17.19	02	0.00	12.35	05	0.00	12.76	07	0.002	3.34	12				0.00	9.45	11
C02	Mutual trust	0.00	9.05	13	0.00	10.20	08	0.00	8.32	12	0.008	2.83	13	0.001	3.64	09	0.00	8.92	12
C06	Sharing risks and rewards	0.00	11.17	09	0.00	9.69	09	0.00	6.08	15	0.013	2.65	15	0.024	2.38	13	0.00	7.7	13
C14	Mutual respect	0.00	6.44	17	0.00	4.90	18	0.00	8.18	13	0.046	2.08	16				0.00	6.95	14
C17	Resource sharing	0.00	7.64	14	0.00	6.98	15	0.00	7.00	14	0.000	4.27	09	0.001	3.66	08	0.00	6.51	15
C16	Ethics and discipline	0.00	7.14	16	0.00	7.12	14	0.00	5.53	16	0.001	3.49	11	0.002	3.44	10	0.00	5.39	16
C09	Informal agreements	0.00	6.19	18	0.00	5.27	17	0.00	4.57	18				0.037	2.18	14	0.00	5.2	17
C12	Long term relationships	0.00	9.08	12	0.00	5.47	16	0.00	3.97	19							0.00	4.67	18
C13	Contractual flexibility	0.00	5.16	19	0.00	4.48	19	0.00	4.82	17							0.00	4.30	19

However, only sixteen (16) characteristics out of nineteen are highly important for the improvement of *health and safety* performance of infrastructure development projects. Further, almost all these RC characteristics demonstrate a lesser contribution level for *health and safety* performance compared for time, cost and quality. Results revealed that the construction industry experts perceive the *environmental performance* as the least effected performance area through the RC concepts and only fourteen characteristics are important. Experts viewed that, this is because it is mandatory for all the construction projects to follow rules and regulations imposed on environmental protection hence the value of RC characteristics in this regards tends to fall behind these legal requirements.

3.2. BEHAVIOUR OF SIGNIFICANT RC CHARACTERISTICS

3.2.1. COMMON/MUTUAL PROJECT GOALS (C05)

RC aligns every participant's effort on fulfilling a joint task, and hence concentrates the 'focus' of all the parties on the work issues rather than contractual issues (Rowlinson and Cheung, 2004; Khalfan *et al.*, 2007) while minimising conflicts (Bennett and Jayes, 1995). Reflecting this, t-test results established 'common goals' as the top most significant factor contributing to the project performance in related to all five areas (refer Table 2).

The study revealed that the unit formed with two or more contracting parties is considered as a small company by the employer and is expected to perform joint tasks. Thus, experts expected that, the parties would share the project scope among them and better perform their part of work while achieving the overall project targets.

3.2.2. CONTINUOUS EFFORT ON IMPROVING PERFORMANCE (C08)

Continuous improvement reviews pave the way to address the important issues immediately and motivate the recovery of falls in performance with no delay before propagating into an unrecoverable failure (Bennett and Jayes, 1995; Thomas and Thomas, 2005).

In the local practice, the unit formed with parties in a RC system continuously draw their attention on improving performance as they are compelled by the joint investment of resources and shared scope of work in the project. Further the experts believed this has contributed significantly to improve the project performance though it was not embrace the systematic procedure of periodically measuring and improving performance against established KPIs, as expected in perfect RC systems.

3.2.3. COMMITMENT TO ACHIEVE PROJECT TARGETS (01)

'Commitment' implies a person's intention to try or to keep trying for a goal (Leung *et al*., 2004). Goal commitment among construction parties is the key to achieve project targets (Liu 1999 cited Leung *et al*. 2004 p.701) by making the participants more agile and flexible in achieving the project outcome (Walker, 2002). As viewed by the industry experts, all partners in the RC system are committed to project targets due to resource contribution and limited scope for one partner.

3.2.4. ENTHUSIASM FOR PROFESSIONAL DUTIES (C18)

Enthusiasm makes the project participants to be agile to perform their duties, to be flexible, adaptable and responsive to changes and challenges and to work co-cooperatively and collaboratively to achieve project goals (Walker, 2002). As revealed by this survey, enthusiasm is highly important for all performance areas of infrastructure projects. Further it identified that, contribution towards shared scope and resource in the RC system makes all parties more enthusiastic on performing the given tasks and duties.

3.2.5. WORKSHOPS (C10)

Workshops in RC systems are conducted for establishing mutual objectives and problem resolution process (Bennett and Jayes, 1995), roles of parties and work processors (Swan and Khalfan, 2007) and selecting partners (Yeung *et al.,* 2012). Though this is not well functioned in SL, industry experts believed that conducting workshops could have a higher impact on the project performance. Workshops, by facilitating face-to- face discussions serves as a better communication medium that improves awareness of all the parties regarding the project matters and supports to raise and to solve problems jointly (Cheng *et al*, 2004). Further, it provides the project participants the opportunity to draw initial plans and to control the procedures to achieve anticipated outcomes (Swan and Khalfan, 2007). Thus, it is expected that workshops could highly improve quality performance of these projects.

3.2.6. OPEN AND EFFECTIVE COMMUNICATION (C04)

Shortfalls in timely communication of information, exchange of ideas and maintenance of open and direct lines of communication between all project participants can block the smooth flow across all activities in a project as construction projects involve several phases, activities and a number of professionals with different expertise (Chan et al., 2006; Cheng et al., 2001; Chan and Kumaraswamy, 1997). Moreover, strong cross-links through effective communication are critical in RC where more than one party work for the same goal, to prevent conflicts and confusions. For instance, when work done in one phase or one party provides inputs to the other phase or party hence if not communicated properly conflicts and confusions occur impeding the total project performance.

3.2.7. INTEGRATED TEAM BUILDING (C11)

Relational contracts in Sri Lankan context are generally formed between client-client, contractor-contractor or consultant-consultant. Thus, even though team building between parallel parties exists, integration of demand and supply sides do not exist in local practice. Hence there is lack of opportunities for local practitioners to appraise its bursting benefits.

However, it is recognised that "integrated team building" could motivate the parties to perform in the best way by making the parties to assume individual and collective responsibilities (Austrlian Constructors Association, 1999), by making the ownership of the outcome to be held by all the team members (Mclennan, 2000) and by bringing together wider range of ideas (Construction Excellence, 2004).

3.2.8. RELATIONAL SELECTION (C20)

Relational selection includes early, unbiased, performance linked, transparent and value focused selection and harmonious negotiation arrangements (Palaneeswaran *et al*., 2003). Thus, it minimises the risk of time and cost overrun resulted from high possibility of change orders through contractor selection merely based on lowest bid price as mentioned in Assaf and Al-Hejji (2006 cited Eriksson and Westerberg 2011 p. 200).

In line with realising these benefits, in forming RC systems, local practitioners are motivated to select the party who has more experience, related skills, capacities and better performance records. However, industry experts further revealed that considerations for soft and behavioural parameters expected in perfect RC systems are lacking in local selection practices.

3.2.9. COOPERATIVENESS AND COLLABORATION IN RELATIONSHIPS (C03)

Collaborative or co-operative relationships urge the parties to rely on negotiations in resolving claims before any legal procedures (Bresnen and Marshall, 2000a), leading to reduction in transactional cost (Rahman and Kumaraswamy, 2002). In addition, Rahman and Kumaraswamy (2002) advocated that contractor-consultant co-operation lead to early, favourable and justified solutions for claims and variations and contractor-client co-operation ensures the progress. Contradicting to these highlighted benefits, t-test results indicated middle level of importance (Rank= 9) for overall project performance. This may be due to hindered benefits triggered by the weak collaboration between client-contractor and client-consultant in the local practice.

3.2.10. IMMEDIATE PROBLEM RESOLUTION AT LOWEST POSSIBLE LEVEL (C07)

RC normally appraises the relationship with more value and hence the contracting parties are in a position to mutually discuss and solve if a problem arises, and hence contribute towards saving time and transactional cost (Walker and Hampson, 2003). This study is also identified that early resolution of problems is a significant characteristic in RC systems as all parties could avoid disputes through clear splitting up of work scope among them. JV Agreement too promotes settlement of any dispute in good faith, through negotiations and mediation before referring it to the arbitration.

3.2.11. MUTUAL UNDERSTANDING (C15)

Mutual understanding is recognised as team members' understanding on the position of other members in the project team, others' goals, needs and confronted difficulties, enabling to achieve project targets (Black *et al*., 2000; Khalfan *et al.*, 2007). As expressed by industry experts, in local RC systems, it provides the opportunity for all parties to understand the interests and goals of each other. For instance, the background created by RC makes the parties attentive on tracking whether the others focus on the project goals.

3.2.12. MUTUAL TRUST ON COMPETENCE AND SUPPORTIVE BEHAVIOUR (C02)

In the construction environment, trust means decision to become vulnerable or dependent on another party whose behaviour is beyond the control, in return for successful project completion (Munns, 1995). Researchers conducted in several countries (e.g. Rahman *et al*., 2007) revealed that 'mutual trust' is the most important factor facilitating RC while 'lack of trust' is one of the top most deterring factors. Absence of trust requires checks and controllers, which consumes resources adding to cost (G. Thomas and Thomas, 2005). By trusting the contractor, consultant's time is not wasted on always supervising the contractor instead get enough time to creatively focus on the project (Rowlinson and Cheung, 2004). However, it was highlighted through the survey that mutual trust exists at a lower level in the Sri Lankan practices.

3.2.13. SHARING RISKS AND REWARDS (C06)

According to industry experts, Relational Contracts make the parties to agree the percentage share of each party with respect to profit, loss and benefits, in order to prevent problems among them. Sharing risks and rewards changes the attitude and behavior of all team members to work hard in achieving targets (Zaghloul and Hartman, 2003). However, industry experts revealed that, pain share/gain share arrangement including the client's participation as stated in ACA (1999) is not practiced in the local industry and hence such benefits are not appraised.

3.2.14. MUTUAL RESPECT (C14)

As viewed by industry experts, responding favourably to a request made by the other party, is an example for the existence of mutual respect in the project environment and is an essential feature when two parties get together and performing a job. Further according to them, the project is automatically adjusted to deliver the best outcome if each party respect the others' requirements. However the highlighted benefits are not fully absorbed due to lack of practices in the local industry.

3.2.15. RESOURCE SHARING (C17)

Sharing resources enables the project to consume best resources of each participant and also enables the project to be benefitted with more appropriate procedures and adequate finance (McLennan, 2000). In general, RC allows project participants to pool their resources including financial resources, knowledge, expertise, technology and skills for joint management (Carrillo, 1996; Walker and Johannes, 2003). In the local practice, joint venture which is the most common RC system in Sri Lanka, are formed in situations where the resources of one contracting company are not enough to carry out a certain project and further companies seek new business opportunities through the strengths of the other partners such as reputation, stable position, business relationships etc. Thus, there is an avenue created for resource sharing through this current practice. However, it is at its adolescent stage in the local industry.

3.2.16. *Ethical Conduct and Discipline (C16)*

Trust based RC approaches encourage the parties to conduct in an ethical manner (Rowlinson and Cheung, 2002). Presence of unethical behaviour of construction professionals such as negligence, incompetence, misconduct, lack of duty of care results in poor quality and further, time and cost is wasted for repair and reconstruction work (Abdul-Rahman *et.al.,* 2010). Besides according to them, construction professionals owe responsibility to the general public. Therefore, concern on good quality of work, environmental protection and health and safety of workers and neighbours are essential aspects. Due to different regulations and practices in the local industry, practitioners are geared to maintain this characteristic.

3.2.17. *Informal Agreements without Legal Enforceability (C09)*

RC approaches involve informal agreements such as verbal promises, letter of intent etc (Rahman and Kumaraswamy, 2002). According to industry experts, there is a mutual agreement (Memorandum of Understanding) between the joint venture parties to agree on resource allocation and on other matters within the unit but are not important for the employer to know. Further, they serve as records on what has been agreed between parties. Moreover, industry experts expressed that this provide flexibility in course of work affecting favourably to the project outcome.

3.2.18. *Long -term Relationships (C12)*

RC approaches induce long-term effect either through series of exchanges (e.g. in strategic partnering) or through one-off but long term contracts (e.g. in PPP/PFI) (Smyth, 2006). According to expert view, mutual understanding developed through working more closely together in a similar arrangement, makes it easier to carry out the work and thus more successful outcome is achievable in terms of time, cost and quality. This is supported by the view of Palaneeswaran *et al*. (2003) that is, long term relationships lead to stronger commitments and closer bonds. Contradicting to these highlighted benefits, local expert mentioned the disadvantages of creating “monopoly” along with these long-term business relationships.

3.2.19. *Contractual Flexibility (C13)*

RC brings in flexibility into the contracts by considering the contracts as relationship between the project participants (Macneil 1980 cited Rahman and Kumaraswamy 2002 p.46). According to local industry experts, mutual agreement between the parties in the RC system can be changed through negotiations. However it is possible only for certain matters and circumstances, even though according to literature, flexibility is a basic characteristic in RC. The t-test indicated that this feature contributes to time, cost and quality performance while is the least effective contributor to overall performance. Contractual flexibility provides the background for effective risk management through facilitating the risks to be managed continuously according to changing circumstances (Rahman and Kumaraswamy, 2005a).

4. Summery and Conclusions

The aim of this research study was to explore how Relational Contracting (RC) systems contribute to improve performance of infrastructure construction projects. Twenty-one RC characteristics were extracted through the literature survey and pilot survey, which are expected to be incorporated in perfect RC systems. Nineteen out of the identified twenty-one characteristics were established through questionnaire survey as significantly existent characteristics in RC systems in the Sri Lankan construction industry. ‘Resource sharing’ is the most strongly existing characteristic. Finally, impact of identified RC characteristics on infrastructure development project performance was assessed by analysing the questionnaires through t-tests. All of the 19 characteristics which significantly exist in RC systems, were proven as significant contributors to improve time, cost and quality performance where only 16 and 14 characteristics were identified as highly important for ‘health and safety’ and environmental performance respectively. ‘Continuous effort on performance improvements’ is the most significant contributor to improve time performance. ‘Mutual project goals’ is the most important characteristic for both cost and environmental performance improvements while ‘Commitment to achieve project targets’ is the characteristic affecting to the highest degree on both quality and ‘Health and safety' performance. Further, most of the characteristics have a stronger importance level for the time, cost and quality performance than for the 'health and safety' and environmental performance. In addition, majority (13) of strongly existing characteristics in RC systems in Sri Lanka are important for all performance areas. Among 19 RC characteristics, 'Mutual project goals' is the most powerful feature in achieving total performance of infrastructure projects. Besides, interviews with industry experts revealed that some RC characteristics in Sri Lankan practice incorporate only the basic concepts but not the exact procedures as defined. These RC characteristics in Sri Lankan industry, contribute to improve infrastructure development project performance, only up to the extent that these basic concepts exist.

Thus, the research discloses the level of relational qualities in the present RC systems in Sri Lanka as well as the effective level of each RC element on different performance areas of infrastructure development projects. Accordingly, the industry practitioners are benefitted through this research in adopting the RC systems designed in the best way to deliver the anticipated project outcome while addressing the weaknesses in the current practice. Moreover, the research study encourages the usage of RC systems by affirming on the value of relational concepts on the construction industry.

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REPORTING PROCEDURE OF CONSTRUCTION ACCIDENTS IN SRI LANKA

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ABSTRACT

A cohesive and centralised recording system of occupational accidents is a significant element of construction industry of any country which requires an effective reporting procedure to feed information into it. It is a valuable management tool that can be used as an aid to risk assessment, to prevent deaths, injuries and ill health conditions, and to minimise costs for accidental losses. However, the absence of an effective reporting procedure will form shortfalls in management of occupational accidents. Sri Lanka is one of the countries that suffers from lack of an efficient recording system. It is revealed that ineffectiveness of existing accident reporting procedure is the main cause for this gap. Therefore, it created a necessity to study the existing reporting procedure of construction accidents in Sri Lanka with the aim of upgrading it by addressing its gaps. Accordingly, the research problem was approached through a document survey and an expert survey which followed by semi structured interviews. Ten experts who are involved in industrial health and safety management were interviewed. The findings revealed that safety representatives of most of the construction organisations reluctant to report to the Labour Department through the district factory inspecting engineer when incidents occur, due to unawareness of legal provisions and burden of paper work. Further, other organisations such as workmen's compensation department; insurance companies; hospitals and police stations, where construction accidents are reported, are not properly linked with the Labour Department. Therefore, Labour Department as the ultimate data storekeeper does not get steady flow of information from any party. Owing to this, seven strategies were established to lift up the adeptness of the existing reporting system through establishing proper links for efficient information feeding.

Keywords: *Accident Reporting Procedure; Centralised Accident Recording System; Construction Accidents; Construction Industry.*

1. INTRODUCTION

Safety at contemporary construction industry of Sri Lanka has become one of the complex issues due to its higher accident rate (De Silva and Wimalaratne, 2012). When compared with other industries, it is rendered that the construction industry is the most vulnerable with a reported number of annual accidents; in-between 750-900 (Amarasinghe, 2011). Among them 50-60 were fatal (Amarasinghe, 2011). Further, this annual figure represented a more than 30 percent of accidents which was about 13 times higher than in the other industries (Rameezdeen, *et al*., 2003; De Silva and Wimalaratne, 2012). However, these statistics have not disclosed the real situation, as only less than 60 percent of accidents are reported (Amarasinghe, 2011). Therefore, it is clear that, in Sri Lanka the underreporting of construction accidents rate is high. There are many reasons contribute for the underreporting of accidents. Among them, International Labour Organization (ILO) shows the limited coverage of reporting procedures as one of the major reasons (ILO, 1996). Further ILO has highlighted that the proper collection, reporting and recording of data concerning occupational accidents are instrumental in prevention and to develop preventive measures of accidents (ILO, 1996). Accordingly, the research was focused on identifying the gaps in the existing reporting procedure of construction accidents in Sri Lanka with an intention of enhancing the procedure by addressing its gaps.

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2. OCCUPATIONAL ACCIDENTS AND CAUSES IN CONSTRUCTION INDUSTRY

The International Labour Organisation (ILO) (1996) has defined the term, "occupational accident" as an occurrence arising out of or in the course of work which results in fatal injury or non-fatal injury. It classifies these accidents under several categories based on the nature of the injury, bodily location of the injury, type of accident and the agency. As cited in Rameezdeen *et al*. (2003), Laufer and Ledbetter (1997) defined the occupational accident as, "an unplanned, not necessarily injurious or damaging event that interrupts or disrupts the completion of an activity". Further their classification of the level of injury based on loss of working days has gained more popularity among others (Rameezdeen *et al*., 2003).

Though the accidents are common for all industries, construction industry has recorded higher accident rates which result in absence from work, loss of productivity, permanent disabilities and even fatalities (Fung *et al*., 2005). Therefore, construction sites are often labeled as unsafe, dangerous or hazardous places to work (Sherratt *et al*., 2013). It is revealed that most of the severe construction accidents, injuries as well as economic losses have been occurred due to the negligence of safety in construction sites (Laufer, 1987). Further, human errors are highlighted as one of the main causes for construction accidents (Hinzeand, 2000). Ahamed, *et al*. (2011) discloses that 90% of occupational accidents are due to unsafe acts or unsafe behaviors of workers. These accidents were reported as operating without authority, working with moving machinery, working without personal protective equipment, wearing dangling clothes, unsafe lifting, carrying and placing, using hand instead of tools and unsafe handling of hazardous material (Ahamed, *et al*., 2011). In a nut shell, Goh and Chua (2002) classified these causing factors of these accidents under three broad headings; immediate, underline and safety management system (SMS) (refer Table 1).

Table 1: Factors Affecting Construction Accidents

Immediate Factors	
Substandard Physical Conditions	Substandard Acts
1. Substandard plant/ machinery/ equipment/ tools	1. Extraneous Acts
2. Substandard construction material	2. Improper equipment usage
3. Substandard structures/parts of structure	3. Inappropriate response to emergency
4. Substandard work environment	4. Omission of basic safety measures
5. Other substandard physical condition	5. Spatial error
	6. Improper work procedure
	7. Other substandard acts
Underlying Factors	
Job Factors	Personal Factors
1. Factors related to designers	1. Lack of knowledge/skill
2. Factors related to operatives	2. Mental/psychological factors
3. Factors related to project management/ corporate	3. Improper motivation
4. Factors related to site management	4. Physical/physiological factors
5. job factors	5. Other personal factors
SMS Failures	
Inadequate: (A) System, (B) Standards or (C) Compliance in one of the following elements	
1. Safety policy	9. Safety inspections
2. Safe work practices	10.Maintenance regime for all machinery and equipment
3. Safety training	11. Hazard analysis
4. Group meetings	12.The control of movements and use of hazardous substances and chemicals
5. Incident investigation and analysis	13. Emergency preparedness
6. In-house safety rules and regulations	14. Occupational health program
7. Safety promotion	
8. Evaluation, selection and control of sub-contractor	

Source: Goh and Chua (2002)

Among these causing factors, lack of safety at construction sites, lack of safety awareness programs for workers, negligence of workers and limited legislation requirements for health and safety of the workers at the construction sites are considered as main reasons for the construction accidents in Sri Lanka (Somasundaraswaran, *et al*., 2005).

3. PROFILE OF CONSTRUCTION ACCIDENTS IN SRI LANKA

The figures of occupational accidents are published annually in many countries but reliable data are available only in a limited number of countries (Hämäläinen, *et al*., 2006). In most of the countries, only less than 20 percent of construction accidents are reported (ILO, 2003). Statistics of accidents in developing countries including Sri Lanka are also not based on proper accident recording and notification systems as proper records are not available (Hämäläinen, *et al*., 2006).

However, in recent years (during 2009 to 2012), based on the available statistics at the Industrial Safety (IS) Division of the Labour Department in Sri Lanka, the reported fatal and non -fatal accident are high as indicated in other countries (refer Table 2). Among these accidents, it is revealed that in 2012, 30% of the accidents are from construction industry though it was about 25% in the period of 2004. Further, it was found that the number of fatal accidents in the Sri Lankan construction industry is the largest contributor to fatal accidents followed by mining and quarrying (Rameezdeen *et al*., 2003).

Table 2: Profile of Construction and All Other Industrial Accidents (2009-2012)

Year		**2009**	**2010**	**2011**	**2012**
Construction and All Other Industries	Fatal	76	64	60	80
	Non-Fatal	1449	1456	1313	1319
	Total	1525	1520	1373	1399

4. UNDERREPORTING OF CONSTRUCTION ACCIDENTS

As mentioned, the data shown in Table 2 do not denote the true number of construction accidents due to the underestimation error. Such underestimation occurs when organisations fail to record employee injuries and illnesses (organisational-level under-reporting) and report to the authorised bodies or when employees fail to report injuries and illnesses occurring at the workplace (individual-level under-reporting) to the relevant officers (Probst and Estrada, 2010). Accordingly, organisational level and individual level underreporting are originated mainly due to lack of awareness of legal reporting requirements, penalties for poor record keeping infrequently levied on firms, and burden of completing the relevant paperwork posing to firms, etc. (Lim, 2007).

Under the Factories Ordinance of Sri Lanka, it is compulsory for all factories to report all occupational accidents and injuries caused to workers and if it causes loss of three days, to the Labour Department. Further, all organisations are required to send a report of accidents time to time. However, this is not acclaimed by all organisations due to many reasons. Among them, a lack of an institutional mechanism to ensure accountability and to make the surveillance system was highlighted. Therefore, one of the Labour Department’s key challenges is lack of reporting of workplace injuries to them (Sunday Times, 06th October 2013).

5. BENEFITS OF REPORTING AND RECORDING OF CONSTRUCTION ACCIDENTS

Operations are unsuccessful without adequate recordkeeping, which enables to learn from past experience and make corrections for future operations (Department of Industrial Relations, State of California, 2005). Therefore, the Department of Industrial Relations, State of California trot out the importance of record keeping of accidents at work. It reveals that records of accidents, work-related injuries, illnesses and property losses serve as a valuable purpose which affords an efficient means to review the current safety and health activities for better control of operations, and to plan future improvements (Department of Industrial Relations, State of California, 2005). Oregon State University

(2009) states that accident records supply information to identify trends to help control conditions and acts that contribute to accidents and managers can use them as an indicator of the financial impact of unsafe behaviour and the need for loss control efforts and information can be combined with medical and disability cost figures to reflect the direct cost of occupational accidents. Further, Health and Safety Authority, Dublin (2006) says keeping records will help safety representatives to check whether remedial measures have been implemented and to monitor the effectiveness of such measures.

The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995, UK, as cited in Scottish Centre for Healthy Working Lives (2014) shows that with the information provided through recording and reporting, the enforcing authorities are able to help and provide advice on how to reduce injury, and ill health in the workplace. Such surveillance data can also be used to put forward an evidence-based rationale for the introduction of new legislation and/or guidance.

6. RESEARCH METHODOLOGY

A comprehensive literature review was carried out relevant to the research objectives with the aim of identifying the construction accidents and their causes, profile of construction accidents of Sri Lanka, reasons for underreporting of construction accidents and importance of an effective accident reporting procedure for construction industry.

A pre study survey was carried out to document the existing accident reporting procedure used in Sri Lanka. Further an expert survey was carried out to validate the documented reporting procedure and to explore its prevailing gaps. Ten experts who are expertised in the area of occupational safety and health were selected for this task and in-depth interviews were conducted. The professional experience of these experts were ranged from ten years to over twenty five years and hold managerial level positions in the industry. Further four most experienced experts were again interviewed to identify enhancing strategies to proposed recommendations to address the shortfalls in the existing system.

7. EXISTING REPORTING PROCEDURE OF CONSTRUCTION ACCIDENTS IN SRI LANKA

In the existing reporting procedure (refer Figure 1), if an accident arises in a construction site, the flow of reporting procedure from the workplace to the Department of Labour can be demonstrated and depicted as follows:

1) If there is a victim who suffered from an injury, hospitalisation of him/her immediately relies with the safety representatives of the site.

2) Immediately after the hospitalisation, the records of the accident should be kept in internal documents of the workplace. Keeping internal records of accidents will help safety representatives to develop prompt arrangements to prevent recurrence of similar kind of accidents and to monitor the effectiveness of such measures. Therefore, internal records are maintained as an accident prevention strategy of most construction organisations.

3) The Section 61(Notification of Accidents) of Factories Ordinance No. 45 of 1942, as last amended by the Factories Amendment Law No. 12 of 1976, describes that, “where any accident occurs in a factory (i.e. in a workplace) which (a) causes loss of life to a person employed in that factory; or (b) disables any such person for more than three days from earning full wages at the work at which he was employed; or (c) makes any such person unconscious as a result of heat, exhaustion, electric shock or inhalation of irrespirable or poisonous fumes or gases, etc., written notice of the accident, in such form and accompanied by such particulars as may be prescribed, shall forthwith be sent by the occupier or manager or the superintendent (in the case of an estate factory) to the District Factory Inspecting Engineer (DFIE)” who is appointed for the respective district.

   Accordingly, if an accident categorises under one of the above conditions, the employer is liable to send the notice of accident via “Form 10” to the DFIE who is appointed for that particular district. Further, the Section 92(01) of same ordinance prescribes that a “general register” known as “Form 11” should be maintained to record every accident which reported with Form 10. Further a copy of this general register is required to send to the DFIE once in six months.

4) If the injury is caused to the workman while he is working in the course of his employment and if it is resulted in the total or partial disablement of the workman for a period exceeding three days, only then the commissioner for workmen's compensation is informed. (Workmen Compensation Ordinances Nos.19 of 1934). The commissioner for workmen's compensation should be informed via "Form Q". In addition to the Form Q, the insurance company is informed, when the organisation claims the insurance coverage.

5) When a victim is made an insurance claim, the insurance company and the commissioner for workmen's compensation work closely in order to release the compensation by the insurance company.

6) The insurance company is further, bound to provide information of such construction accidents to the Department of Labour.

7) If the victim is hospitalised, it is the medical officer's responsibility to keep records of the patient in the hospital itself and inform the police post of the hospital or nearest police station via a note. Afterwards, the police can start their investigations on the incident.

8) The section 61 of the factories Ordinance further describes that "where any accident causing disablement is notified, and after notification thereof results in the death of the person disabled, notice in writing of the death shall be sent to the DFIE by the occupier or manager or the superintendent (in the case of an estate factory) as soon as the death comes to his knowledge". Accordingly, when the death comes to the employer's knowledge, DFIE is informed by the employer via a "notice of death", and when the city coroner is informed by the hospital, the post-mortem is carried out and report will be provided.

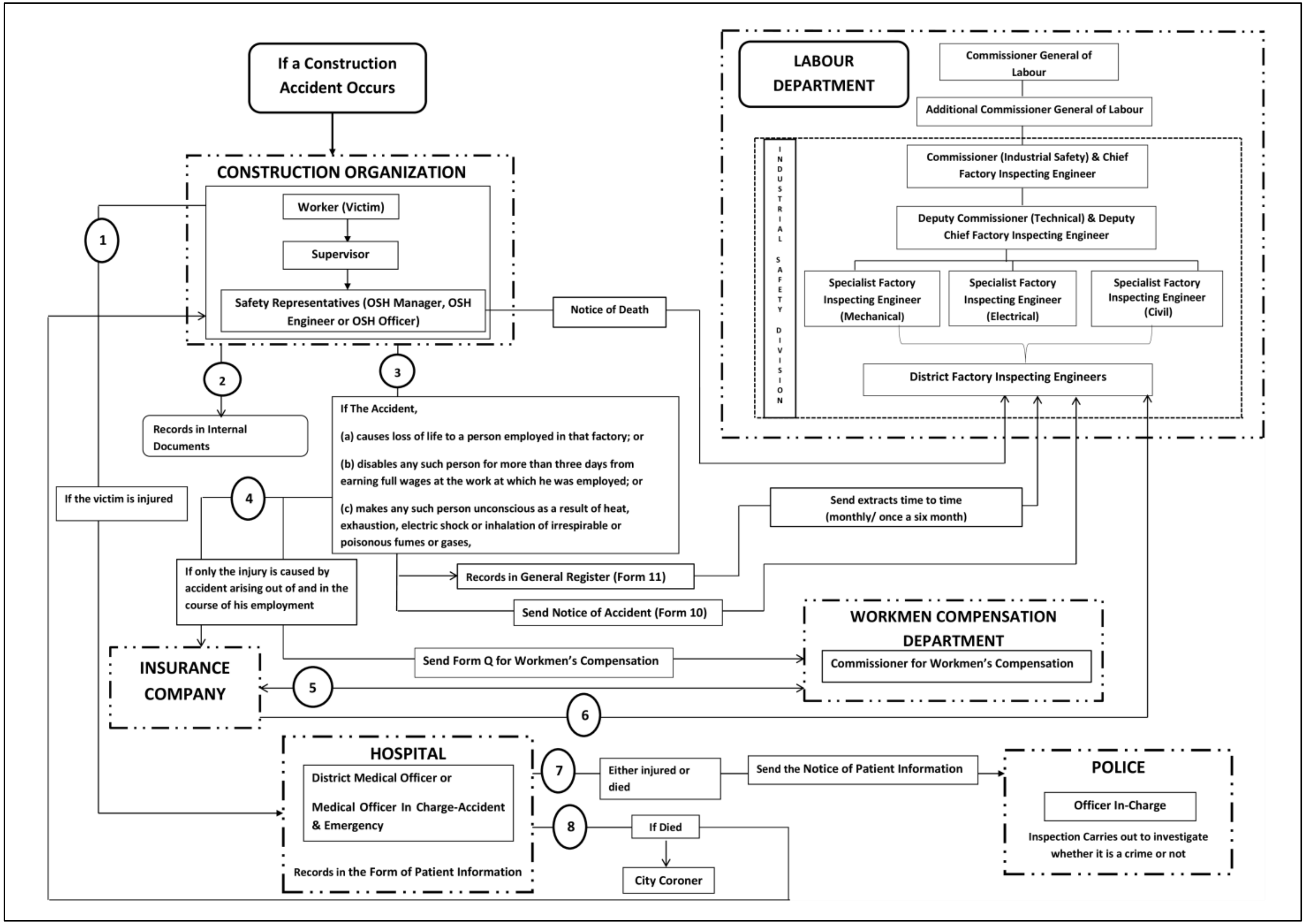

Figure 1: Existing Reporting Procedure of Construction Accidents in Sri Lanka

8. GAPS IDENTIFIED IN THE EXISTING REPORTING PROCEDURE

Eight numbers of gaps which are prevailing in the existing accident reporting procedure were identified and discussed under the following headings. They can be also made known as barriers for maintaining an effective and centralised recording system for construction accidents.

- **Gap 1: Lack of Reporting and Recording Systems at Organisational Level**

  Lack of a systematic approach for reporting and recording of accidents within the organisational/site level is the substance gap in the existing reporting procedure. Lack of knowledge, awareness, systems, management commitments and other facilities were identified as main shortfalls at this level. Additionally, a strong leadership towards inculcating OSH was identified as a deliberating need. However, shortages in qualified safety representatives in the construction industry could hamper producing these leaderships.

- **Gap 2: Lack of Reporting to Department of Labour**

  Due to the inattention, lack of awareness of legal reporting requirements and burden of completing paperwork, most of the safety representatives of the sites and workers do not persuade to report accidents occurred in the sites via notice of accident form (Form 10) to the respective DFIEs. They consider that involvement of the department of labour would create additional distress to them. Further, it was revealed unavailability of a stringent monitoring procedure for following up the law has debilitated the need of reporting. However, the construction organisations who have already obtained and who are being implementing OSHAS 18001, track this practice as it has been mandated by OSHAS 18001.

- **Gap 3: Lack of Reporting of Minor Accidents (less than three working days from earning full wages at the work)**

  As per the Factories Ordinance No. 45 of 1942, it is compulsory for all factories to report accidents and injuries caused to a worker if the worker is absent for three working days due to an OSH incident. Therefore, the accidents that categorise under "less than three working days from earning full wages at the work" are not reported to any authorised body as there is no legal requirement in the law. However, most of the organisations maintain internal documents for recording of all type of these accidents including "near misses" as a strategy to prevent recurrence of same incident.

- **Gap 4: Unavailability of a Centralised Recording System**

  It was observed that, instituting a centralised recording system is a burning need to formalize a precise and efficient reporting procedure which is considered as one of the main causes for under reporting. However, lack of staff, infrastructure, lack of integration between relevant authorities/departments and capital for devising and maintaining such centralised recording system were highlighted as indeed de-motivators. Further bureaucracy of the existing administration system in relevant authorises/departments would create a hindrance to execute a cohesive and centralized recording system.

- **Gap 5: Poor Relationship between the Department of Workmen Compensation and Department of Labour**

  If a personal injury is caused to a worker by accident arising due to his employment and if it is resulted in the total or partial disablement of the workman for a period exceeding three days, the employer has the responsibility to pay compensation for the victim in accordance with "Commissioner Workmen Compensation" ordinance (Workmen Compensation Ordinances Nos.19 of 1934). Therefore, almost all the accidents which have brought personal injury for a workman for a period exceeding more than three days are informed to the workmen compensation department. However, due to no legal provisions to disseminate information within the system, there is no avenue created to share those information with the IS division of the department of labour.

- **Gap 6: Poor Relationship between Insurance Companies and Department of Labour**

  Most of the employers have insured their employees against the liability of workmen's compensation. Therefore, in a case of an accident which is described under above points (refer Figure 1), the employer informs insurance company simultaneously to workmen's compensation department in order to claim the compensation for the victim or victims. Even though the insurance companies should have an information flow between them and the workmen's compensation department, they are not bound to maintain a proper affiliation with the department of labour during such information sharing.

- **Gap 7: Poor Relationship between Hospitals and Department of Labour**

  As it is clearly mentioned in the law, a medical officer is bound to inform the chief inspecting engineer of the department of labour only if he identifies a serious occupational disease which has arisen due to the employment in construction industry (Factories Ordinance No. 45 of 1942). Except that, there is no direct informing procedure of the victims to the department of labour, and thus not often practising. However, medical officers inform the police post or nearest police station upon a serious accident when the victim is hospitalised, even with no prescribed form or procedure to report. The experts reveal that less staff for administrative work of hospitals may be the main reason for poor record keeping and reporting to department of labour.

- **Gap 8: Poor Relationship between Police and Department of Labour**

  Figure 1 demonstrates that if a victim is hospitalised and are at critical stage, the police should be informed by the hospital and then investigations will be proceed. Under these situations, the police however not liaise with the department of labour to make a record of the incident. Thus, department of labour may not get an opportunity to investigate it.

9. STRATEGIES TO MITIGATE IDENTIFIED GAPS

Seven probable strategies to mitigate the gaps identified in Section 7 were compiled through findings of the expert survey and discuss in this section.

- **Strategy 1: Establishment of Independent Division to Maintain a Centralised Occupational Accident Recording System**

  Establishing an independent division for collecting required data and maintaining a recording system is vital to eliminate all the gaps identified in the existing system. This division should have the authority to compile information of the department of labour, department of compensation, hospitals, police and insurance agencies. Further, it can be formalised to conducting risk management programmes, awareness programmes and develop guidelines related to accident prevention and accident reporting to enhance safety management.

- **Strategy 2: Employing Qualified Safety Representatives for Construction Organisations**

  Employing qualified safety representatives is essential in construction organisations/sites to enhance safety management to and thus to eliminate the first two gaps in the reporting procedure. Safety representatives can be Health, Safety and Environment (HSE) officers, Occupational, Safety and Health (OSH) Engineers or OSH Managers. In Sri Lanka, basic qualifications of safety representatives are not defined and therefore, in most of the construction sites, not properly qualified officers are engaged. Therefore, it is recommended defining qualifications that should be required to appoint qualified safety representatives. In line with this, sufficient educational programmes should be introduced to produce qualified people in this arena.

- **Strategy 3: Introducing Prescribed Information Sheets for Accident Reporting**

  Other than the existing forms such as Form 10, Form 11 and Form Q for reporting accidents, a similar set of forms can be introduced to the (1) hospitals, (2) police stations or hospital police posts, (3) workmanship compensation department and (4) insurance companies for reporting to the IS division of the labour department or to the proposed independent division (if it forms). As such, five information flow paths can be created to a centralized reporting system.

When the form is introduced, the responsible officials of the organisations are bound to send them to the relevant authorities and thus 5th, 6th, 7th and 8th gaps would be effectively eliminated.

Having establishing these forms, to avoid the repetition of the same information feed by different forms from different organisations, an identical reference number for each victim can be used by all organisations. For instance, it was suggested that it is better to use National Identity Card number as the reference number. On the other hand when the same information comes through five flows, it can be used as a tracking mechanism for under reporting of accidents by relevant bodies and directs to take legal actions against those particular bodies.

Instead of introducing these forms, it was suggested to introduce an online portal which can save time, cost and manpower required to maintain the proposed centralised system. It is an easy option to go for as sufficient technology is available in Sri Lanka.

- **Strategy 4: Awareness Programmes on Accident Records and Reporting**

  The awareness programmes on safety and health of workers are conducted frequently. However, the awareness programmes on legal provisions and importance of documentation of accidents are not seen as important aspect. It was identified that some of the staff who work as safety representatives even do not aware the legal provisions. Therefore, awareness programmes should be increased in order to mitigate the first two gaps of not recording and reporting the accidents.

- **Strategy 5: Decree to Implement the SLS OSHAS 18001 Standard**

  The Institute for Construction Training and Development (ICTAD) as the governing body of construction industry in Sri Lanka, can decree to implement the SLS OSHAS 18001 for all grades of construction companies in Sri Lanka. SLS OSHAS 18001 is particular on documentation. Therefore, it will lead every construction organisation to document each and every aspect of health and safety of construction sites mitigating the first and second gaps of poor recording and reporting of construction accidents.

- **Strategy 6: Continuous Monitoring on Notification of Accidents**

  Introduction and availability of legal provisions do not persuade the people to follow them up. A strict monitoring process should be there in order to encourage the following up the law. This can be promoted through creating stringent legal provisions. However, this is not possible with existing human resource capacities, financial capacities and with other amenities provided to relevant authorities. On the other hand, introducing promotional schemes, safety excellence awarding systems can motivate organizations towards better reporting.

- **Strategy 7: Encourage Construction Organisations to Apply for OSH Excellence Award**

  National Institute of Occupational Safety and Health of Sri Lanka in collaboration with Ministry of Labour and Labour Relations offers awards for organisations who excel in occupational health and safety. This would be a strategic movement to motivate construction organisations to follow OSH guidelines and practices and eventually to fill the first two gaps in the prevailing under-reporting condition. Further, such a promoted OSH culture will reduce risks of occupational accidents.

10. SUMMARY

It is vital to have an effective accident reporting and recording system for construction industry in Sri Lanka. Since the accident rate of construction industry is getting high, it is a responsibility of the authorised bodies to working closing together to reduce the situation. Having said that, availability of reliable data of accidents are important. However, with lack of effective accident reporting procedure and a centralised recording system for industrial accidents, consolidating a reliable data source has become a difficult task. Therefore, the construction industry in Sri Lanka suffer with information shortages.

The research makes it clear that there are prevailing gaps in the existing accident reporting procedure, which creates inefficient recording system. These gaps are discussed as eight barriers. Therefore, further study focuses to find out probable suggestions that can be adopted to mitigate them. Establishment of another institution under Department of Labour to maintain a centralised industrial accident recording system, appoint qualified safety representatives for each construction site of construction organisations, continuous monitoring of following up the legal provision on notification of accidents, introduction of a prescribed information sheet for all organisations who are involved in a case of an industrial accident and after an accident or development of an online portal, increase the awareness programmes on importance of maintaining records and reporting of industrial accidents, decree to implement the SLS OSHAS 18001, for occupational health and safety management systems and encourage the construction organistions to apply for OSH excellence awards were found as strategies to mitigate the gaps in existing accident reporting and recording procedure of Sri Lanka. These proposed strategies can be considered in establishing a centralised recording system for construction industry to enhancing its image of OSH.

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RESPONDING TO THE BUILT ENVIRONMENT CHALLENGES: DESIGN FOR ADAPTATION

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ABSTRACT

The current building stock in the UK only vaguely fits the evolving needs of businesses and users. This leads majority of existing buildings to be demolished, renewed, refurbished or redundant. However, maintaining a redundant building stock is economically unviable and a socially unacceptable solution, as these buildings generate no income while the building owners are responsible to pay taxes for the buildings. Also, scrapping and rebuilding relatively young buildings is neither economically nor socially desirable and does not correspond with the demand for durability and sustainability. Therefore, to survive a more complex array of needs, modern buildings are required to be designed to improve space, environmental and safety standards and adapt for potential change situations. In this sense, adaptable buildings focus on potential bespoke solutions that are flexible for varying customer needs. Buildings with adaptable potential may survive in the immediate future; however, the traditional maladaptive buildings will remain as redundant stock unless they find a correct use. This paper investigates the design strategies for adaptability in middle range buildings (4-12 storeys) while explaining the capacity of adaptable buildings to respond to the built environment challenges. A comprehensive literature review was undertaken to identify the strategies and design parameters for adaptability in buildings, and eleven interviews were carried out among the construction professionals to identify the practicality of promoting adaptable building strategies within the UK construction industry. NVivo-10 software was used to analyse the empirical data, and the results explained market demand, user requirement, stakeholder awareness and challenges like cost, risk, technology and existing planning policies are the key issues that need to be addressed when promoting adaptable buildings.

Keywords: *Benefits and Challenges; Built Environment Challenges; Design for Adaptability; Strategies and Parameters; Sustainability.*

1. BACKGROUND

The built environment challenges appear in the areas of 'environment considerations' (Geraedts, 2008), 'innovations in technology' (Flanagan and Tate, 1997; Nutt, 2000), 'planning and policy issues', 'social requirements, 'political forces' (Gann and Barlow 1996) and 'economic considerations' (Arge, 2005; Douglas, 2006). Recent consideration has been given to identify how the new building stock could be adapted for 21st century challenges (Henehan and Woodson, 2003; Sheffer and Levitt, 2010). This requires an understanding of the extent of changes required to the existing building stock and the lessons learnt for designing new buildings to survive future markets. To respond these macro level challenges, buildings need to change in terms of the 'function' they house, the 'capacity' to achieve the performance required for the population they hold and the 'flow' of reacting to internal and external environmental forces (Slaughter, 2000). Buildings that are unable to survive with the aforementioned challenges would become prematurely obsolete or require substantial refurbishment or demolition.

The existing building stock is an important physical, economic, social and cultural capital to any nation (Kohler and Hassler, 2002). However, building obsolescence seems as one of the critical dilemmas

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associated with the existing building stock. The strategies of 'adaptive reuse' (Kincaid, 2000) and 'brownfield developments' (Silverthorne, 2006) are discussed in the literature as better means for using existing buildings in a sustainable way. Itard and Klunder (2007) explain that building transformation, if structurally possible, is a much more environmentally efficient way to achieve the same results than demolition and new construction. In a way, reuse benefits are seen as not only a lower cost option for the typical end-user, but also in the value of retaining the style and character/heritage of buildings, the solid build qualities and the appropriateness of their location (Ball, 1999). The UK government legislation (e.g. landfill tax) and policies (e.g. Strategy for Sustainable Construction 2008) encourage building owners/clients to rethink the possibilities and potential avenues for reusing space (adaptive reuse) while extending the functional lifespan of their buildings. In addition, the government is seeking alternative strategies to minimise the building redundancy while promoting optimum use of the existing building stock in urban centres; it encourages conversion of redundant office and retail space into leisure, service and/or residential uses rather than demolition and renewal (Davison *et al.*, 2006). Nevertheless, the conversion processes might be neither economical nor practical in many circumstances; therefore, there is a real need to design new buildings for potential adaptations.

Even though there are number of ongoing discussions on promoting adaptable buildings a very few applications could be identified within the UK construction industry. Therefore this paper aims to investigate what adaptable buildings are, their design considerations, benefits and challenges, which of course would help relevant authorities/stakeholders to support in their decisions. However the study focused on middle range buildings (4-12 storeys) as they represent the highest percentage in the building stock.

2. RESEARCH METHODOLOGY

Data were collected from an extensive literature review and eleven semi structured interviews. Literature review was focused to identify the design strategies and parameters for adaptable buildings. Semi-structured interviews were used to understand the need and practicality/challenges of promoting adaptable buildings within the UK construction industry. The interview questionnaire was piloted with three academic members of one of leading higher education institutions in the UK for feedback on clarity and readability. The selected interviewees were from architecture, quantity surveying, structural engineering, planning and policy development disciplines and their lengths of experience varied from less than 10 years to more than 30 years, demonstrating a good spread of experience. The collected data were organised manually by coding text and breaking it down into more manageable pieces. Moreover, NVivo 10 software was used to further code those data to create nodes.

3. NEED FOR DESIGNING BUILDINGS TOWARDS FUTURE POTENTIAL ADAPTATION

As an innovative solution to many of the above problems, consideration is now being given to exploring the possibilities of integrating adaptable potential in new buildings. The term 'adaptation' often appears in the manufacturing industry, although recently it has also emerged in the building industry as an innovative strategy for minimising the premature retirement/redundancy of buildings. Many of the manufacturing products are industrialised, produced on a mass scale, short in lifespan and highly focused on customer flexibility compared to construction products (Hashemian, 2005). These adaptable techniques from the manufacturing industry could perhaps be exploited to a certain extent in construction practices when products need to show similar characteristics, like flexibility, customisation and adaptation. The importance of 'adaptable buildings' in construction businesses has been recently discussed by many authors, particularly with regard to various facets of building adaptations, such as 'technical and functional performance of adaptable buildings' (Gann and Barlow, 1996; Slaughter, 2001; Kendall, 2003; Larssen and Bjorbery, 2004), 'stakeholders' motivation and benefits' (Arge, 2005; Kalita, 2006), 'regulations and policies' (Kincaid, 2002; Adeyeye *et al*., 2010), 'sustainability' (Kincaid, 2000, Thomsen and Flier, 2009) and 'risk' (Remoy and Voordt, 2007).

4. ADAPTABLE BUILDINGS

This paper explains 'adaptable building' as an innovative strategy for designing new buildings towards future adaptations. It extends the economic and functional lifespans of buildings (Douglas, 2006). Specifically, adaptable buildings can be defined as 'dynamic systems that carry the capacity to accommodate a set of evolving demands regarding space, function, and components' (Adaptable Futures, 2012). A maladaptive building is one that cannot match the new demand placed upon it, whether it is technically unviable or cost-inefficient. The line between the two can often become blurred and depends on a set of exogenous and endogenous demands that can be determined through careful evaluation. Correspondingly, open building design (Habraken, 1980; Kendall, 1999) provides a similar conceptual philosophy but falls short of providing clear criteria for evaluation, focusing primarily on the separation of long and short-term components. The literature reveals adaptable buildings as a nascent but strong and practical solution to defeating the problem of building redundancy (Douglas, 2006; Kronenburg, 2007; Adaptable Futures, 2012). However, the critical challenge to building designers/owners/ developers is the inability to prepare for unforeseeable futures, mainly because of the difficulty in predicting future uncertainties, risks and the costs of changes (Ellingham and Fawcett, 2006). Property developers are more concerned with the returns on their investments in adaptable properties; however, economic evaluation for adaptable buildings needs to be conducted to provide the needed 'hard' evidence to show that these buildings provide a more economically sound answer than a typical fit-to-use solution. Thus, there is a need to respond to the increasing pressures of rapid changes in user needs, technological shifts, altered working and living patterns and other forces that render buildings obsolete before the depletion of their service lives (Fernandez, 2003).

4.1. DESIGN STRATEGIES

In specific to this study the 'Strategy' means how the building endures change over time (Adaptable Futures, 2012). In a way it is a plan of action designed to achieve a long-term or overall aim (Oxford Dictionary, 2010). 'Adaptability' has different meanings for different interest groups. Table 1 encapsulates the variety of strategies that were discussed in the literature to define adaptability in the built environment. These strategies 'can effectively reduce life cycle costs by allowing a timelier and less costly response to a dynamic environment, which adds costs measured in terms of money, time, and complexity' (Ford and Garvin, 2010, p.54). Among these terms, 'adaptability' and 'flexibility' are often engaged to bring a similar kind of meaning. 'Adaptability' is used to explain macro level issues like 'capability of social uses' and 'flexibility' is used to address micro level issues like 'capability of physical changes' (Groak, 1992). By contrast, Schneider and Till (2005) define 'flexibility' as a common term to represent the capability of buildings to accept both different social uses and physical arrangements. Beisi (1993) argued that providing adaptability is not a one-time strategy but should guarantee the long-term possibilities of use. The strategies of durability and design for disassembly are closely related to adaptability, which in different forms enhance long-term environmental performance (Russell and Moffatt, 2001).

Table 1: Design Strategies for Adaptability

Author / year	Generality	Flexibility/Versatility	Elasticity/Extendable/ Expandable/Scalable	Convertible	Dismantlable/ Separable/ Partitionable	Disaggregatable	Prefabrication/ Standardisation	Overcapacity	Movable	Rearrangeable	Reusable/Recyclable	Refitable	Multi-functional	Integratable	Universal	Modularity	Ejectable	Exchangeable
Gann and Barlow (1996)							•	•	•	•								
Blakstad (2001)		•	•		•								•					
Robertson and Sribar (2002)			•		•						•			•				
Arge (2005)	•	•	•													•		
Douglas (2006)		•	•	•	•	•												
Verweij and Poelman (2006)			•															
3DReid (2006)		•	•	•					•		•	•						
Geraedts (2008)		•	•		•				•	•					•		•	•
Pati *et al.* (2008)		•	•	•														
Gijsbers *et al.* (2009)		•			•		•		•									

Having considered aforementioned design strategies and available terminologies for adaptability in buildings the following frame-cycle (refer Figure 1) was developed by the Adaptable Futures research team.

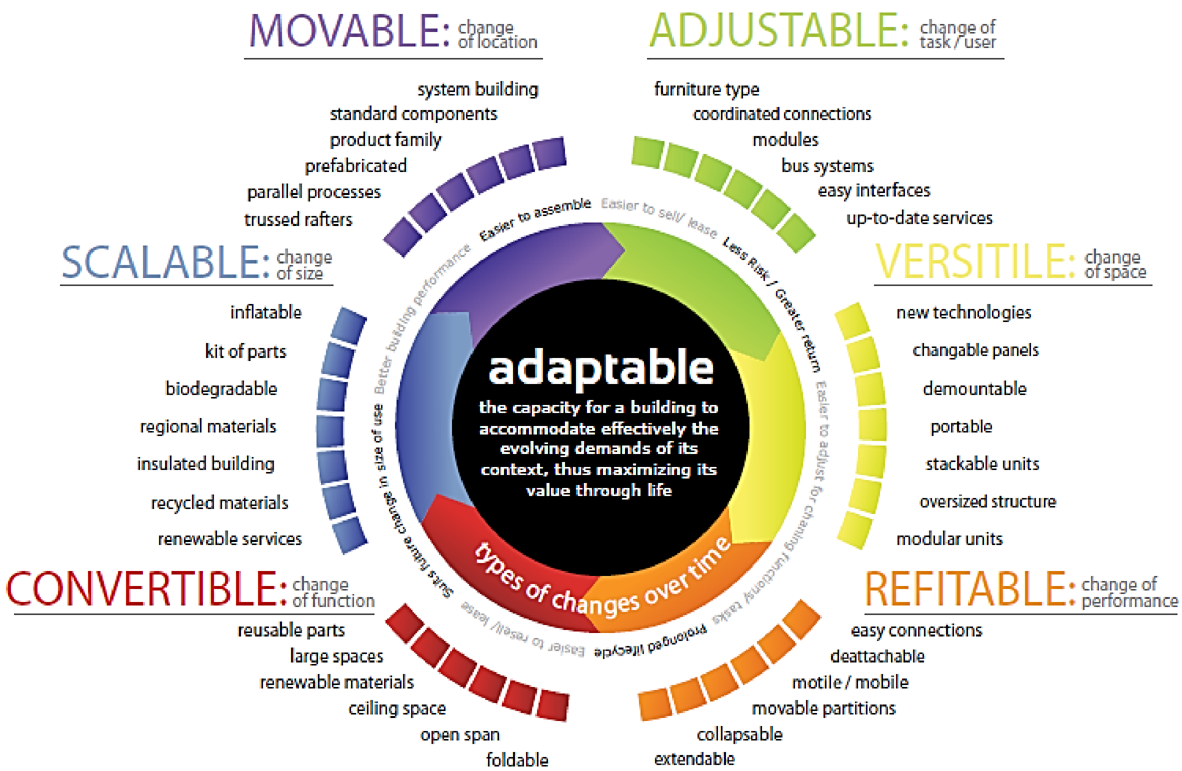

Figure 1: Design Strategies for Adaptability in Buildings (Frame-Cycle)
Source: www.adaptablefutures.com (2012)

The frame-cycle considers six main strategies and their associated sub-strategies. The ‘adjustable’ strategy relates to the ability of buildings to change their tasks. This considers alterations of furniture type, coordinated connections and module systems. ‘Versatility’ explains the ability to change the internal space of a building. The strategy takes into account up-to-date service systems, changeable panels, demountable/portable and stackable units, oversized structures, modular units and easy connections. ‘Refitability’ elucidates the ability to change building components, which considers detachable, degradable, mobile, movable and collapsible components. The term ‘convertible’ determines the ability of buildings to shift between different uses/functions. This requires internal and external alterations to buildings. Considerations are given to managing large spaces, renewable materials, ceilings and open spaces to facilitate those uses. The ability to change the size of the building is reflected by ‘scalability’. ‘Extendible’, ‘elasticity’, and ‘expandable’ also have similar meanings to scalable. This considers such alterations as reusable components, renewable services, recycled materials, insulated buildings and kits of parts. The ability to change location is explained through ‘movability’. This encourages system buildings, standard components, product families, and prefabricated and parallel processes. However, semantic permutations/dependencies between some of the aforementioned strategies create difficulties in clustering them into specific individual categories. For example, design for potential change of use (convertible) connects with the scalable and refitable aspects of building components. Brand (1994) provides strong evidence that buildings are not just static objects but that they are dynamic. There is, for instance, a model (shearing layers of change) of the way a building tears itself over time. Hence, designing a building to adapt to a potential change of use means allowing its hierarchical layers to change; each in its own time scale. Most importantly the consideration should pay for identifying the critical design parameters when designing buildings towards potential adaptation.

4.2. DESIGN PARAMETERS

Literature reveals different design parameters for adaptability in buildings (refer Table 1). One or few of those design parameters might be influenced when designing buildings to accommodate aforesaid strategies. From a web-based survey among 32 architects, Manewa (2012) identified the parameters like plan depth, floor to ceiling height, structural design, fire safety design, services system, and building size, height and proximity are the influential parameters for change of use (convertible). There are buildings with adaptable features; however, it is uncertain whether they fully match the performance of their new purpose-built facilities because of their restrictions as regards to layout and height (Douglas, 2006). Gregory (2006) states it is significant that the buildings best suited to adaptation are those with the most generous ceiling heights. For example, ‘the inherent flexibility of many of the Georgian and Victorian domestic buildings has been very influential in the development of ideas of adaptability in new work, especially housing and industrial buildings’ (Farrell, 1979 p.59). Moreover, Kincaid (2000, p.158) explains that ‘too much floor to floor clearance is wasteful in both the long term and short term; too little is always wasteful in the long term as use changes, and in the short term hostile to energy use and people’.

Moreover, Douglas (2006) and 3DReid (2006) discuss the influence of storey height in building change of use scenarios. In addition, Saari and Heikkila (2008, p.240) explain that the ‘long-term adaptability of old industrial properties has been particularly good thanks to high floor heights and long spans and their conversion to office and residential use has been possible and relevant in several recent construction projects’.

Table 2: Design Parameters for Adaptability

Author/ year	Floor to ceiling height/ Storey height	Technical span	Structural load	Building orientation	Space/Area/Volume for system zone	Building height	Building width	Building size	Floor plan	Availability/Elevator/Vertical circulation	Location/Site condition	Floor systems/Raised floors	HVAC system & distribution	ICT service	Plug & play elements/ Interchangeable components	Ceiling zone/Soffit quality	Organisation of space	Separation of functions/ Decoupling	Fire sprinkling changes/ Fire safety design	Plan depth	Structural design/Slabs	External façade/Cladding design	Acoustic/Noise insulations	Physical access/System access flexibility/Proximity	Interior walls (movable)	Electricity supply	Central corridors	Inter-system interaction	Intra-system interaction	Internal layout/Layout predictability	Flow	Core design	Partial/Phased demolition
Gann and Barlow (1996)						•	•						•						•	•	•	•	•	•						•			
Ratcliffe and Stubbs (1996)	•																																
Keymer (2000)					•										•									•				•	•	•	•	•	•
Heath (2001)	•																			•	•						•						
Larssen and Bjorberg (2004)	•	•	•		•					•	•		•	•							•				•	•							
Arge (2005)	•	•					•					•	•	•	•	•	•	•	•														
Richter and Laubach (2005)												•	•						•		•	•		•									
Verweij and Poelman (2006)								•	•																								
3DReid (2006)	•									•		•				•			•	•	•	•		•									
Gijsbers (2009)	•				•						•			•				•						•	•			•					
Rawlinson and Harrison (2009)	•	•		•			•			•			•			•				•	•			•									

Moreover, Kaputsyan (1974, p.280) identified storey height as a significant economic parameter whilst emphasising that the ‘economic level of mass-scale housing construction for a specific period is stimulated by the standard requirements, thus formulating such economic parameters as the upper limits of the floor space of flats, the height of a storey, the number of lifts and the like’. Hence, storey height was considered in this study to be a significant design/economic parameter for change of use in buildings. Higher storey heights increase the flexibility of buildings. Having identified the influence of ‘floor height/storey height’ in building change of use, it is necessary to explain how this parameter could affect the economic considerations of buildings. Lau (2001) identified ‘floor height/storey height’ as one of the marketable factors that clients/owners most often consider when buying or leasing a space.

4.3. SUSTAINABLE CONSIDERATIONS

Sustainable buildings have the in-built ability to adjust to changing circumstances and technologies, without excessive waste and conflict (Kendall and Ando 2005). In its simplest form, sustainable futures are ones in which the basic means of human livelihood get easier, human opportunities become richer, and nature's diversity is more sustained and not only in the rich parts of the world (Holling, 2000). In this sphere, adaptable buildings can be defined as ‘dynamic systems that carry the capacity to accommodate a set of evolving demands regarding space, function, and components’ thus maximising the through life value (Adaptable Futures, 2012).

‘Sustainability’ has been an important element of all real estate developers’ agendas, regardless of time and market perspective (Arge 2005). If buildings were designed for potential adaptations, it would be possible to successfully respond to the aforementioned built environment changes. On the other hand, sustainability will be a major criterion in judging future buildings and their installations. Among the factors that play a role here are savings in base materials, minimising waste production, ease of dismantling, adaptability and deposit money arrangements. Flexible buildings and installations that are readily adaptable to changing conditions respond to this trend (Geraedts, 2008). Buildings designed to maximise the potential for adaptation to accommodate different uses are required, together with appropriate transportation and communication infrastructures (Gann and Barlow, 1996). ‘The construction industry must respond by creating new buildings that are adaptable, allowing their operating facilities managers to readily respond to changing space use demands throughout their life’ (Webb *et al*., 1997, p.318). A building that is ‘unfit for purpose’ leads to it being redundant in its functional tenures. In this light, either design for adaptations (DFA) or design for short lifespans can be considered. However, the latter is not always appreciated in the sustainable agenda as many of the construction materials are economical in long structural lifespans, although reusable solutions have not been very well practised in the construction history recently. Hence, this paper promotes the potential for extending the functional lifecycles of buildings through DFA as opposed to designing for shorter lifespans. However, the future-proof endeavour seems complicated and risky because the decisions taken today need to be justifiable tomorrow, and perhaps these decisions may only vaguely fit tomorrow's requirements. In this regard, spending too much over budget for an unattainable target could also be considered a waste.

5. RESULT AND DISCUSSIONS

Eleven interviews were carried out among the construction professionals to identify the practical considerations of promoting adaptable buildings within the UK construction industry and they were analysed through NVivi-10 software. Tools in NVivo can be used for a variety of purposes, for instance models can be used to explore ideas as well as to present them to others (Wiltshier, 2011). A model was used to reflect on initial nodes and determine possible issues on promoting adaptable buildings within the UK construction industry (refer Figure 2). The results revealed that the buildings which are designed to enable future change represent a good long term investment however it is less practical to design one building to respond to all the aforementioned changes. In fact, the buildings which respond to pre-designed changes will bring 'value for money' and also 'improve the sustainability' in long term. To promote adaptable building within the UK construction industry, consideration should be paid on issues such as of market demand, user requirements, stakeholder awareness, cost and risk factors, and also available government initiatives for promoting adaptable construction.

The interviewees further stated that a typical commercial developer will initially raise finance for a development to pay a consistent yield on their investment over a 25 - 30 year period. By increasing their upfront costs on a development to provide the flexibility for a future 'non-specific' change they will be increasing their investment. Then it will take longer to repay which is a risk. As there is no certain plan for the future requirements there is no guarantee that their investment is a profitable one. Therefore, a more robust methodology is required at the beginning of the project to help developers'/clients' investment decisions. Developers are in business to make money to maximise return on every lowest spent. Therefore in reality they would accept to incorporating features in their buildings that tick the eco/sustainability box, but mostly provided it does not cost anymore. Therefore to have a market where design for future adaptability, the current entrepreneurs need payback in their lifetime, not in the future. However there are no concessions to achieve this. The whole structure of business, company or national, is run on achieving the yearly financial targets. There is little investment for a sustainable future no matter what most companies may expound. Moreover, if the government incentivised developers (through tax relief or grants) to consider this in their developments it could lead to better sustainability/environmental improvements. However, in real terms in depends on the location, for instance if a building is proposed to design for multi-use a city centre will realistically always be prioritised for commercial use. The Government could lead an initiative in their Public Sector Construction Programmes for specific areas they wish to regenerate strategically.

In a way, more buildings would be adaptable if there were 'legislation/regulation', 'increase in building values and rents', 'change in planning rules', 'greater standardisation', 'change in industry mind' and, most importantly, 'clarity over cost/benefit' and 'greater use of lifecycle cost'. In addition to economic considerations, the benefits to society at large (the neighbourhood) and the environment were also noted.

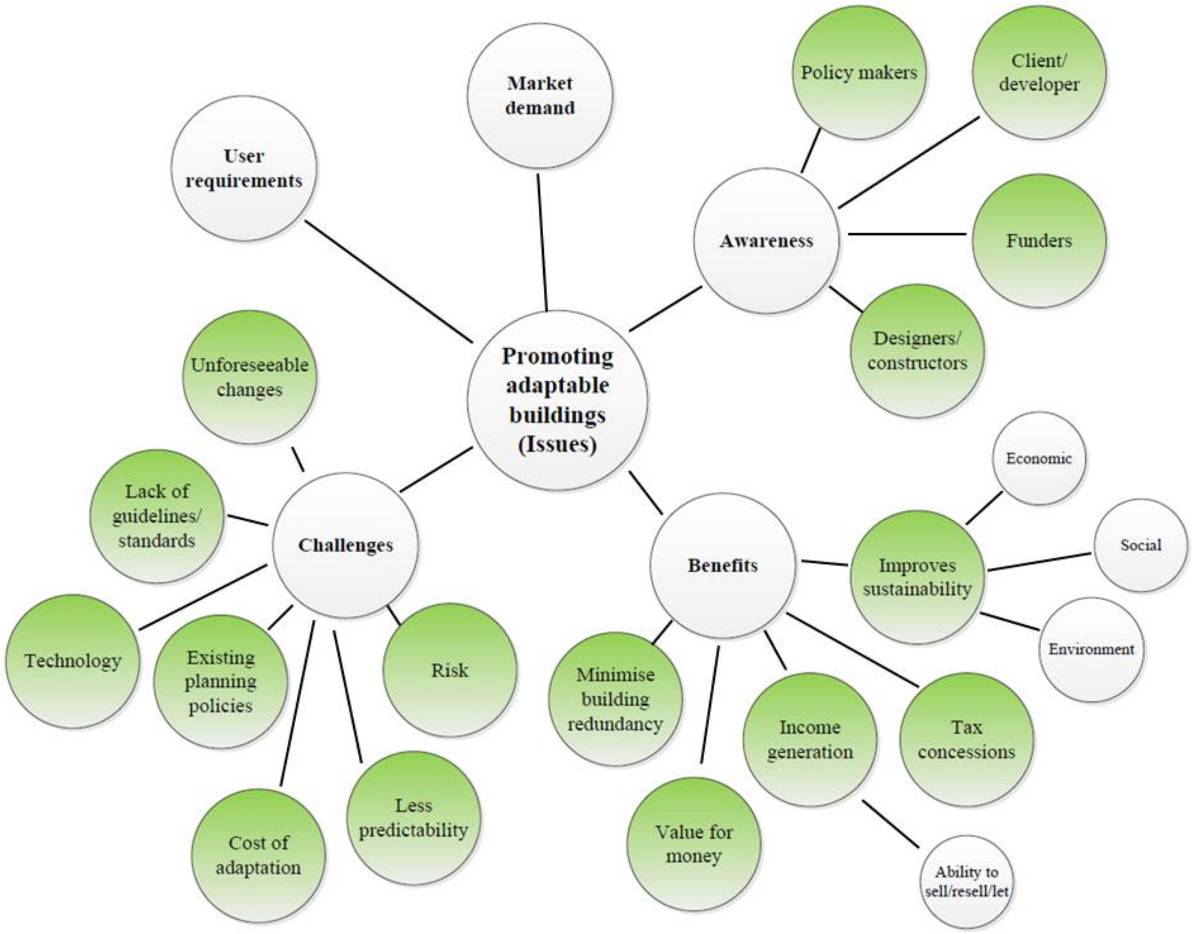

Figure 2: Issues Associated with Promoting Adaptable Buildings in the UK Construction Industry

6. CONCLUSIONS

Social, economic, political, environmental, technological, physical and legal factors demand built environment changes. However, the existing building stock lacks adaptable performance and vaguely responds to these challenges. As a result, the existing building stock has a tendency to remain redundant or is scrapped and rebuilt. In a way, adaptive reuse empowers a 'new life' into existing buildings; however, physical, economic, environmental and policy constraints appear to be the major difficulties in continuing such adaptations within existing buildings. Therefore, design for adaptation is considered as a means for empowering adaptable potential in new buildings to respond to the built environment challenges. This process (DFA) considers the lifecycle extendibility of buildings, which takes into account different adaptable strategies, design intelligence and design parameters for improving adaptable potential in new buildings. These adaptable strategies are able to provide reasonable design solutions to micro and macro level changes.

From the empirical investigations it was identified three key entities which are user needs, market demand and stakeholder awareness are required to be balanced to achieve a successful adaptable product. However, there are few challenges. Existing planning and policy issues appear to be major constraints to designing buildings for potential adaptations. Even though the exogenous demand arises for implementing adaptable strategies in built environments, a lack of owner/developer motivation tends to cause them to disregard these adaptable concerns in their brief. Existing design practices also need improvements to encourage adaptable potential in the new building stock. The expected benefits from adaptable buildings would be the motivation factor to promote adaptable buildings within the UK construction industry. The key benefits like value for client's investment, income potentials, tax concessions, remedy for redundancy and ability to improve sustainability are highly acknowledged. Whilst a plethora of literature exist on the importance of the need to either design with adaptability in mind, or making the existing buildings adaptable, the focus is mainly on the features of the building (product) such as scalability, convertibility, etc. However, given the complex stakeholder engagement, information intensity, process complexities etc, it is necessary to develop an appropriate environment which facilitates the development of adaptable buildings. Therefore, this study will further look in to how adaptability can be empowered in terms of incentives, processes, stakeholder engagement and technology (especially the rapidly developing information technology enabled tools such as Building Information Modeling - BIM) leverage. It is expected that the outcome will contribute to the achieving the broader sustainability agenda in the built environment.

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RISK OF CATASTROPHIC EVENTS ON CONSTRUCTION SUPPLY CHAIN

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ABSTRACT

Construction supply chain flow through the entire business process initiated from the demand by the client to create the project, till the demolition of the construction. Catastrophic events are rare events which are difficult to predict its occurrence. However, catastrophic events take place within the construction supply chain; have a severe impact over the project.

Most of the researches on supply chain were keen to understand the factors increasing efficiency and reducing cost. As a result, many findings were there to keep the supply chain live at ordinary times, but at the cost of being vulnerable to disruptions. It was identified that catastrophic events take place in the construction supply chain have not been highlighted in supply chain researches. Therefore, the aim of this paper is to present the catastrophic events take place in construction supply chain and their risk levels.

A comprehensive literature review has laid the initial path to gather current knowledge on catastrophic events in construction supply chain. In order to fill the gaps in literature, a preliminary study has been carried out to gather further information on practical experience with catastrophic events in construction supply chain. The study revealed that although there are number of findings on catastrophic events on supply chain management, the risk levels of these catastrophic events change under different conditions. Therefore, through the findings of the above two phases and the survey carried out among construction industry experts, this paper list out the catastrophic events, ranked according to the risk level under a developing economic and tropical environment. This fascinating strategic finding is a great tool for construction decision makers to fight the risks in construction supply chain.

Keywords: *Catastrophic Events; Construction Supply Chain; Likelihood; Risk Analysis; Severity.*

1. INTRODUCTION

Heightened challenges due to series of catastrophic events that have disrupted economies around the world have prompted academics and practitioners to investigate new strategies to minimise their impact on supply chain. Mentzer *et al*. (2001) defined supply chain as '*a set of three or more entities (organisations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer*'.

Although supply chains exist in any type of organisation, the complexity of the chain to vary greatly from firm to firm, culture to culture and also from industry to industry. The construction industry consists of certain peculiarities, as one-of-a-kind nature of project, temporary multi-organisation, site production, and regulatory intervention preventing the attainment of flows as efficient as in manufacturing (Koskela, 1992). Vrijhoef and Koskela (2000) argued that due to construction peculiarities, supply chain management has specific roles in construction. The construction supply chain primarily represents a series of serial and parallel connections between clients and suppliers leading to the delivery of one or more products to one or more end clients (Vrijhoef and De Ridder, 2005).

Supply chains are increasingly vulnerable to catastrophic events and a diverse set of risks (Knemeyer *et al*., 2009). According to Atley and Ramirez (2010), there are evidence that failure to manage supply chain risks effectively may lead to a significant negative impact on organisations. Such impacts include not only financial losses but also reduction in product quality, damage to assets and loss of reputation (Khan and Burnes, 2007).

Thus, the paper structure begins with a review of construction supply chain management and identification of catastrophic events on construction supply chain. The next section presents the research methodology

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and conceptual framework. Research findings are presented in the fifth section and followed by concluding discussions.

2. CONSTRUCTION SUPPLY CHAIN MANAGEMENT

A major distinction between construction and manufacturing is that the construction industry is project based and of discontinuous nature, while manufacturing industries involve continuous processes and relationships (Segerstedt and Olofsson, 2010). The construction industry is one of the most complex industries, because the total development of a project normally consists of several phases requiring a diverse range of specialised services and involvement of numerous participants. Therefore, it is difficult to control and manage construction projects effectively (Tserng *et al*., 2005). Production in construction is relatively disconnected and fragmented due to the nature of demand and supply systems in construction have traditionally been organised (Vrijohoef and De Ridder, 2005).

Supply chain management (SCM) in manufacturing industry is defined as '*the systemic and strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole'* (Mentzer *et al.*, 2001). Supply chain in construction consists of all the construction business processes initiated from the demands by the client as conceptual, design and construction to maintenance, replacement and eventual decommission of building (Xeu *et al.*, 2007). Further to Xeu and his co-workers, construction supply chain is not a chain of construction businesses with business-to-business relationships, but a network of multiple organisations and relationships, which includes the flow of information, the flow of materials, services or products, and the flow of funds between client, designer, contractor and supplier. Fisher and Morledge (2002) have reported three types of construction supply chains: the primary supply chain, which delivers the materials incorporated into the final construction products; the support chain, which provides equipment and materials that facilitate construction; and the human resource supply chain, which involves the supply of labour. Kumar and Viswanadham (2007) argued that in construction, materials have to be imported many times and it makes supply chain global and more difficult to manage. Vrijhoef and Koskela (1999) stated that actual practice in construction not only fails to address issues of supply chain, but also follows principles that make supply chain performance worse.

3. CATASTROPHIC EVENTS

Stecke and Kumar (2006) showed that there has been a marked increase in the frequency and economic losses from natural and man-made catastrophes. But, Vanany *et al.* (2009) highlighted that catastrophic events have received relatively less attention in the supply chain management literature.

Gilbertson *et al*. (2011) defined catastrophic events as events that are beyond the ordinary or routine and are characterised by being of low probability but high consequence. Mitroff and Alpaslan (2003) identified seven categories of catastrophes as; economic crises (recessions, hostile takeovers), physical crises (industrial accidents, product failures), personnel crises (strikes, exodus of key employees, workplace violence or vandalism), criminal crises (product tampering, act of terrorism), information crises (theft of proprietary information, tampering with company records), reputation crises (logo tampering, rumour mongering), and natural disasters (floods, fires). Wagener and Bode (2006) recognised natural hazards, socio-political instability, civil unrest, economic disruptions and terrorist attacks as catastrophic events. Stecke and Kumar (2006) broadly classified catastrophes into two main parts: man-made and natural catastrophes and further divided them into other sub groups.

Gilbertson *et al*. (2011) identified several catastrophic events that could occur during construction phase as, structural collapse of permanent structure, collapse of temporary works, collapse of plant and equipment such as cranes, major fire, tunnel collapse, and disruption of underground services. Gilbertson *et al*. (2011) identified the most significant factor, which could affect the probability of a catastrophic event in construction industry as the failure to recognise hazardous scenarios and influencing events. Other important factors include lack of site control, interface problems with various parties, lack of checking and competent reviewing and lack of designer's involvement on site.

4. RESEARCH METHODOLOGY

The objectives of this study are to identify likelihood and severity of catastrophic events and their level of risk on construction supply chain. An extensive literature review was carried out to develop a research framework to gather data required for an empirical study. Different types of catastrophes affecting construction supply chain were initially identified using a literature review. The findings of the literature review initiated the pilot survey to investigate the applicability and suitability of literature findings to the Sri Lankan construction supply chain characteristics and conditions. One of the main objectives of the pilot survey was to develop a detailed questionnaire for the main survey.

The conceptual framework developed form the literature and pilot study findings is shown in Figure 1.

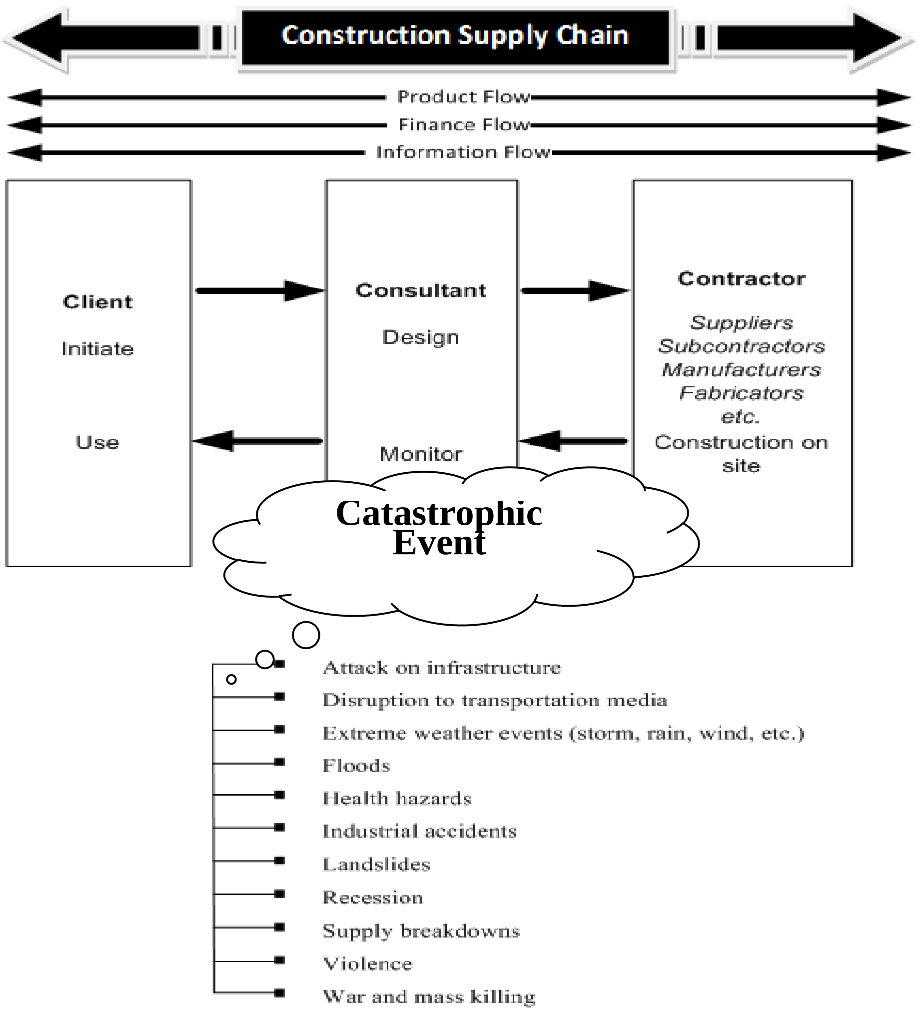

Figure 1: Conceptual Framework

Client, consultant and contractor are the three direct stakeholders in construction industry. The involvement of these parties in typical construction chain is illustrated on the above figure. Client initiates the construction with his need and plan. Based on the client requirement, consultant takes the construction process forward by developing a design which caters the client needs. At the next stage contractor builds a link between suppliers, subcontractors, manufactures and other such parties whose involvement is needed to the construction of the physical model of the consultant's design. After developing a strong link with the necessary outside parties, contractor starts the construction work and consultant monitor the contractor on behalf of the client till the contractor handover the project to the client to use. However, supply chain keeps the construction process live at each of the above mentioned phases. Finance, information and products are flown both ways throughout the construction supply chain to complete the supply chain loop. The smooth flow of these resources is disturbed by the catastrophic events and these events are listed in the figure.

As a result, 31 catastrophic events were identified during the literature review and all the identified catastrophes where presented in pilot survey to analyse their applicability in Sri Lankan construction supply chain. Further, the pilot survey questionnaire was prepared to gather any other catastrophe faced by the Sri Lankan practitioners which is not found during the literature review. Five construction project managers who are involving in construction supply chain management were interviewed during the pilot survey.

Findings of the pilot survey highlighted 14 out of the 31 catastrophic events which were found in literature. Catastrophes such as cyber attacks and biological, chemical and nuclear attacks were not considered for the main survey as they were recognised as not applicable to Sri Lankan phenomenon. Also, few catastrophes were merged to cover a broad area as well as to give a clear idea to the participants of the main survey. For example, catastrophic events such as flood, storm, and wind were taken as one catastrophe named extreme weather events. Further, strikes were renamed as trade union actions to reflect all possible catastrophes related to employees. Finally, 14 catastrophic events identified were used to develop a structured questionnaire for the main survey. Detailed questionnaire was distributed among the experts in the construction industry to identify the likelihood and severity of the catastrophic events that disrupt construction supply chain.

Construction industry experts were selected from C1 grade contracting organisations in western province due to complex nature of supply chain activities carried out by the construction companies of this grade. C1 is the highest grade that can be achieved by a contractor according to the categorisation of Institute for Construction Training and Development (ICTAD), the regulating authority of construction in Sri Lanka. During the study, researchers requested assistance from the initial respondents to identify professionals with similar experience and/or interest. The survey was limited among the contractors who carry their business in western province due to the time limitation. However, it is an area where most of the contractors do business. The detailed survey was then continued with the nominated respondents until obtaining the sufficient number of responds. Hence, snowball sampling method is used for this study. The questionnaires were given to 35 construction industry experts and 32 were responded. Composition of paricipants and their response rate are shown in Table 1.

Table 1: Composition of Participants

Designation	Number of Questionnaires Distributed	Number of Responses Received	Response Rate
Senior Managers	7	7	100%
Project Managers	18	15	83.3%
Planning Engineers	6	6	100%
Purchasing Managers	4	4	100%
Total	35	32	91.4%

The questionnaire used Likert scale to receive the responses for each question. Mean weighted rating was calculated for each catastrophic event in order to identify the likelihood and severity level of catastrophic events.

5. RESEARCH FINDINGS

The most important findings of the survey are summarised in the discussion below, supplemented by a series of tables. Severity and likelihood of different catastrophic events that affect construction supply chain are discussed first, followed by risk analysis of catastrophic events.

All catastrophes do not pose the same type or amount of risk to construction supply chain. For example, war may have the severe consequence such as large number of human and facility losses, while a disruption to transportation media may only affect supplies. Catastrophes such as extreme weather events and landslides may have different consequences on construction supply chain. This makes it difficult for construction organisations to plan their projects to face different catastrophes. Therefore, identification of severity and likelihood of catastrophes may ease the construction planning process.

First part of the questionnaire is focused on the identification of likelihood and severity of catastrophic events that threaten or disrupt the construction supply chain. The likelihood and severity corresponds to "how likely" and "how much" a catastrophe might affect the construction supply chain.

5.1. *LIKELIHOOD OF CATASTROPHIC EVENTS*

The questionnaire used 0-4 likert scale to receive the opinion of respondents regarding the likelihood of each catastrophic event that disrupt construction supply chain. In the particular question, respondents were asked to give their opinion about the level of likelihood based on the scale that indicates; most likely-4, very likely-3, somewhat likely-2, little likely-1 and unlikely-0. This likert scale has five categories and the data range is 4. Therefore, the researcher set the cut off point at intervals of length 4/5, which is 0.8. The new guide to indicate the likelihood of a catastrophic event is; Unlikely (0.00 – 0.80), Little likely (0.81 – 1.60), Somewhat likely (1.61 – 2.40), Very likely (2.41 – 3.20) and Most likely (3.21 – 4.0). Likelihood survey findings are given in Table 2.

Table 2: Likelihood of Catastrophic Event that Disrupt Construction Supply Chain

Catastrophic Event	Mean	p-value	Rank	Likelihood
Unexpected departure of key employees	3.094	1.000	1	Very
Floods	2.906	1.000	2	Very
Trade union actions (strikes)	2.719	1.000	3	Very
Disruption to transportation media	2.688	1.000	4	Very
Supply breakdowns	2.531	1.000	5	Very
Health hazards	2.250	0.946	6	Somewhat
Recession	2.250	0.946	6	Somewhat
Landslides	2.000	0.500	8	Somewhat
Tsunami	1.625	0.002	9	Somewhat
Extreme weather events (storm, rain, wind, etc.)	1.625	0.002	9	Somewhat
Industrial accidents	1.594	0.001	11	Little
Violence	1.531	0.000	12	Little
War and mass killing	1.406	0.000	13	Little
Attack on infrastructure	1.313	0.000	14	Little

According to the survey findings given in Table 2, unexpected departure of key employees, floods, trade union actions, disruption to transportation media, supply breakdowns, health hazards, recession and landslides received p-values greater than 0.05. Therefore, the aforementioned catastrophic events are identified as likely catastrophic events that disrupt construction supply chain. Most of the likely catastrophes that disrupt construction supply chain are non terrorist events except disruption to transportation media. The most likely catastrophe that affects the construction supply chain is unexpected departure of key employees followed by floods, trade union actions, disruption to transportation media and supply breakdowns. According to the ranking list, it is evident that terrorist events have very low likelihood to disrupt the construction supply chain. Because, catastrophes such as violence, war and mass killing and attack on infrastructure are unlikely events for most of the countries.

5.2. *SEVERITY OF CATASTROPHIC EVENTS*

The survey used 1-5 likert scale to get the respondents' opinions on the severity level of the identified catastrophic events. In the particular question, respondents were asked to give their opinion about the severity level based on the scale that depicts; very high severity-5, high severity-4, average severity-3, little severity-2 and very little severity-1. This likert scale has five severity levels and the range of the data is 4. In order to prepare a guide for indicating the severity of catastrophic events, the researchers set the cut off point at intervals of 4/5, which is 0.8. Therefore, the severity of catastrophic events are categorised based on the guide as; Very little severity (1.00 – 1.80), Little severity (1.81 – 2.60), Average severity (2.61 – 3.40), High severity (3.41 – 4.20) and Very high severity (4.21 – 5.00). Severity survey findings are given in Table 3.

Table 3: Severity of Catastrophic Event that Disrupt Construction Supply Chain

Catastrophic Event	Mean	p-value	Rank	Severity
Disruption to transportation media	4.406	1.000	1	Very High
War and mass killing	4.375	1.000	2	Very High
Attack on infrastructure	4.000	1.000	3	High
Tsunami	3.844	1.000	4	High
Supply breakdowns	3.719	1.000	5	High
Violence	3.656	1.000	6	High
Floods	3.625	1.000	7	High
Trade union actions (strikes)	3.625	1.000	7	High
Recession	3.563	1.000	9	High
Health hazards	3.188	0.882	10	Average
Unexpected departure of key employees	3.031	0.585	11	Average
Extreme weather events (storm, rain, wind, etc.)	2.938	0.380	12	Average
Landslides	2.844	0.096	13	Average
Industrial accidents	2.781	0.177	14	Average

All the p-values shown in Table 3 are greater than 0.05. Therefore, all the catastrophic events that were identified from the literature survey and pilot study remained as severe catastrophic events that disrupt construction supply chain. According to the ranking, terrorist events such as disruption to transportation media, war and mass killing and attack on infrastructure are moved to top of the list. It is obvious that those terrorist events have very high potential of disrupting the construction supply chain than any other. Among the natural catastrophes, Tsunami is the only catastrophe that has been selected as the severe catastrophe within the top five severe catastrophes. Industrial accident is the least severe catastrophic event that disrupts construction supply chain.

5.3. *RISK ANALYSIS OF CATASTROPHIC EVENTS*

Risk levels of aforementioned catastrophes are different due to the combined effect of likelihood and severity of the catastrophic event. Risk analysis matrix is a way to focus managerial attention on the high priority catastrophic events that have a high possibility to occur and have a high severity if disrupt to a construction supply chain. The study used risk analysis matrix shown in Figure 2 to analyse the combined effect of likelihood and severity of catastrophic events.

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="5">SEVERITY</td></tr>
<tr><td>Very Little</td><td>Little</td><td>Average</td><td>High</td><td>Very High</td></tr>
<tr><td rowspan="5">LIKELIHOOD</td><td>Most Likely</td><td>Medium</td><td>High</td><td>High</td><td>Extreme</td><td>Extreme</td></tr>
<tr><td>Very Likely</td><td>Medium</td><td>Medium</td><td>High</td><td>High</td><td>Extreme</td></tr>
<tr><td>Somewhat Likely</td><td>Low</td><td>Medium</td><td>Medium</td><td>High</td><td>High</td></tr>
<tr><td>Little Likely</td><td>Low</td><td>Medium</td><td>Medium</td><td>Medium</td><td>High</td></tr>
<tr><td>Unlikely</td><td>Low</td><td>Low</td><td>Low</td><td>Medium</td><td>Medium</td></tr>
</table>

Figure 2: Risk Analysis Matrix
Source: The Scottish Government (2008)

Table 4 shows the aggregate effect of severity and likelihood of catastrophes. This table helps to identify the risk level of each catastrophic event on construction supply chain. The risk analysis matrix guides to identify suitable actions to mitigate the impact of a catastrophe based on the risk level of a catastrophe.

Table 4: Risk Analysis Matrix for Catastrophes

Event	Likelihood	Severity	Risk level
Disruption to transportation media	Very	Very High	Extreme
Supply breakdowns	Very	High	High
Trade union actions (strikes)	Very	High	High
Flood	Very	High	High
War and mass killing	Little	Very High	High
Tsunami	Somewhat	High	High
Recession	Somewhat	High	High
Unexpected departure of key employees	Very	Average	High
Health hazards	Somewhat	Average	Medium
Extreme weather event (storm, rain, wind, etc.)	Somewhat	Average	Medium
Landslides	Somewhat	Average	Medium
Violence	Little	High	Medium
Attack on infrastructure	Little	High	Medium
Industrial accidents	Little	Average	Medium

When comparing the rankings of likelihood and severity, it is obvious that catastrophes that have high severity if disrupt the construction supply chain are not all the time likely catastrophes that disrupt the construction supply chain. For an example, although war and mass killing, tsunami and recession ranked among highly severe catastrophes, they are little/somewhat likely catastrophes that disrupt the construction supply chain. According to Table 4, disruption to transportation media has an extreme risk level on construction supply chain. Supply breakdown, trade union actions, floods, war and mass killing, tsunami, recession and unexpected departure of key employees have high risk level on construction supply chain, where all the other catastrophes have medium risk level. Key catastrophes that require managerial attention are the events that ranked among top of both the catastrophes which likely to disrupt a construction supply chain and have a severe impact if disrupt the supply chain. Stecke and Kumar (2006) established this idea by stating that managers should focus on mitigating catastrophes that have a high possibility and severity of affecting critical components of a supply chain. Nevertheless, it does not mean that management should not look into other catastrophic events.

6. Conclusions and Recommendations

Catastrophic events are unique among other supply chain risks due to low probability of occurrence which is difficult to predict and its' severe impact in terms of magnitude in the area of occurrence. Literature substantiated the vulnerability of construction supply chain for various types of catastrophic events. The aim of this study was to investigate the catastrophes which have a serious effect on construction supply chain under a developing economic conditions and tropical environment. Majority of the catastrophes, which were ranked among the most likely catastrophes to disrupt construction supply chain, are non terrorist events. Findings corroborated the fact that most likely catastrophes to disrupt the construction supply chain are not always the most severe catastrophes. Among the likely catastrophes, unexpected departure of key employees identified as the most likely catastrophic event to disrupt construction supply chain and disruption of transportation media was identified as the most severe catastrophic event. The aggregate effect of likelihood and severity revealed that disruption to transportation media has the extreme risk level on construction supply chain; whereas violence, attack on infrastructure and industrial accidents have medium risk level. All the other catastrophes have high risk level on construction supply chain.

In conclusion, this paper has achieved the research aim by identifying the most critical catastrophes in the construction supply chain under defined criteria. Further, the finding of the research is a strategic tool for decision makers in construction industry. However, the given risk levels are based on particular economic and environment conditions. Therefore, further research needed to be carried out to test the validity of the finding with slight differences in predefined economical and environmental conditions.

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RISK OF USING BIDDING STRATEGIES FOR A CONTRACTOR

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ABSTRACT

Construction contractors often procure projects through a competitive bidding process. Every contractor intends to bid competitively while dealing with the associated risks concurrently. Contractors have developed their own bidding strategies to retain their competitive edge. However, these strategies may carry an inherent risk component that is unforeseen leading to what is termed the 'winner's curse'. The aim of this study is to identify the risks entailed in the different bidding strategies and to explore solutions for the purpose of minimising risks. The research employs semi-structured interviews and a questionnaire survey which was administered to quantity surveying professionals with vast experience in the construction tendering process. Content analysis is used to analyse the qualitative data while statistical measures are used to analyse the quantitative data.

The results of the survey reveal that contractors use bidding strategies mainly for survival purposes that ensure continuous and sufficient work. However, in each bidding activity, their primary objective is a target return on the investment. In addition, fifteen bidding strategies are identified with their allied risk factors. These bidding strategies are ranked according to the risk significance which yields 'Bidding for repetitive jobs' as the one carrying the lowest risk while 'Intuitive manipulation' ranks as the one carrying the highest risk. The study offers a conceptual model that lists methods to minimise the risks of each bidding strategy which provides guidance for contractors to select better-suited bidding strategy rather than random or haphazard selection. Moreover, since some contractors may opt for a risk favourable approach in order to get a high return, the study examines the different risk perspectives of contractors so that they may adopt such bidding strategies with full knowledge of the attendant risks and what strategies are available to minimise risk exposure.

Keywords: *Bidding Strategies; Contractor; Risk; Risk Management.*

1. INTRODUCTION

The construction industry is extremely fragmented and highly competitive in nature (Akintoye and Skitmore, 1992). This makes competitive bidding one of the most critical activities for contractors in the construction industry (Wanous *et al*, 1999). According to Roland (1990), a contractor must formulate an economical approach to secure a steady stream of work which will provide the right volume at profitable prices. Hence, construction contractors develop bidding strategies, either well-considered or haphazard, to guide them in making the right decision in the bid decision-making. According to Passer (2011), the decision-making process entails the conclusive decision of bid/no bid. If the decision is made to bid, strategic adaptations to increase the probability of winning as well as the level of markup should be established. However, Tarek (as cited in Tang, 2004) has pointed out, the risks and uncertainties associated with bid submission can lead to difficulties when deciding on the best-fit bidding strategy against the competition. Often the risk is shared between the parties with contractors coping with the risk and owners paying for the risk (Flanagan and Norman, 1993).

Managing risk in construction projects has been recognised as a key to achieve project objectives in terms of time, cost, quality, safety, and environmental sustainability (Zou *et al*, 2006) with Risk Management (RM) divided into risk classification, risk identification, risk analysis and risk response. Further, risk response has been further sub-divided into four actions: retention, reduction, transfer and avoidance (Flanagan and Norman, 1993). However, it is essential to identify risk in bidding and the risks of bidding strategies when bidding for a project, though a contractor's main aim is to submit a substantially responsive

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bid to win the project by using the appropriate bidding strategies. However, it is important that those strategic decisions do not boomerang on the successful bidder in the form of the 'winner's curse.

According to Ariyarathna (2012), though researches have been conducted on various aspects to the application of bidding strategies used in the construction sector and construction risk, no attempt has been made so far to integrate these studies on risk in bidding strategies. The present study aims at identifying the risks entailed in the different bidding strategies used by contractors and to provide solutions to minimise the identified risks.

To achieve the above aim, it was found necessary to achieve the following objectives:

- To identify the bidding strategies used by contractors;
- To assess the risk of using different bidding strategies;
- To identify RM strategies and their applicability to each bidding strategy;
- To introduce a conceptual model to minimise the risk of bidding strategies.

The rest of the paper is organised as follows. The next section will offer an overview of bidding strategies in construction and ascertain the nature of risk in construction through a literature survey. The following section outlines the research methodology followed by data analysis, which entails the findings of an interview survey and a questionnaire survey in order to demonstrate the type of risks associated with bidding strategies, the magnitude of the risk and the methods of managing the risks associated with bidding strategies. The paper then discusses the results and presents, in conclusion, the conceptual model to manage risk in construction bidding.

2. BIDDING STRATEGIES

Bidding, in general, means the conversion of numbers in a competitive bid after consideration of market factors and risk (Cooke and Williams, 2004). On the other hand, bidding is explained as an invitation to treat by the client and use bidder's errors to his advantage (Carr, 1977). According to Rodriguez (2013), knowledge of how to bid on construction jobs can make the difference between success and failure of a construction contractor because the bidder in competitive bidding is faced with two seemingly incompatible and contradictory objectives: to bid high enough to make a profit and low enough to get the contract (Tang, 2004). Hence, competitive bidding offers abundant opportunities for the application of strategies. However, the application of different bidding strategies depends on the type of client, type of construction work and the size of construction work (Drew *et al*, 2001).

In construction bidding, contractors' decision making on pricing has been found to be subject to exogenous and endogenous variables, which vary in response to the context within which they are considered (Shash, 1993). In order to meet specific objectives while taking care of factors that influence the pricing decision, firms have to adopt some sort of pricing strategy. For instance, a construction firm that is targeting a niche market could do this by tendering for such jobs at a low price level (Skitmore and Akintoye, 1990). According to Fellows and Langford (as cited in Skitmore and Akintoye, 1990), firms may adopt low profit-level pricing in times of economic recession in order to maintain market share or to penetrate a new market. According to Skitmore (1989), only bids derived from a detailed cost estimate along with a realistic markup can be regarded as genuinely competitive. In order to maintain genuine competitiveness, bidding strategies can include different markup policies that may be variable or fixed. Upson (1987) has proposed that the following factors should be given consideration with regard to variable markup policies: work in hand, bids in hand, availability of staff, profitability, ability of the architect or other supervising officers, contract conditions, site conditions, construction methods and programme, market conditions and the identity of other bidders.

2.1. THEORETICAL CLASSIFICATIONS OF BIDDING STRATEGIES

According to Smith (cited in Zoysa, 1997), there are several major types of bidding models: models based on probability theory, regression models and econometric models. Zoysa (1997), moreover, classified them under three major types: mathematical approach, judgmental approach, and artificial intelligence and information technology approach. However, according to the available literature, most of these models cannot be used in actual practice due to the constraints imposed by the real world (Tang, 2004). Therefore, the present study focuses on strategies that have been actually implemented rather than the aforementioned theoretical models which may enjoy currency in academic circles. Among the reasons that function as a deterrence to the utilisation of the models are (i) the overly simplified assumptions on which the models are based which make them impracticable for the purpose of addressing real-world problems; (ii) the unwillingness of most bidders to struggle with sophisticated mathematical models, which makes them rely on their own experience in dealing with problems associated with bidding situations for the purpose of accomplishing organisational objectives" (Tang, 2004). Hence, many of them prefer to rely on their own experience in dealing with bidding situations for the purpose of accomplishing organisational objectives. Boughton (1987) has found out that profit maximisation is the most frequently used bidding objective. Similarly, Friedman's model, which was one of the mathematical approaches to determine bidding strategies, addressed the existence of multiple bidding criteria by listing the objective of profit maximisation as one of the top priorities (Zoysa, 1997). Thus, Friedman's model has been recognised as a practical decision-making model. The discussion above underscores the need for practical approaches in order to bid effectively (Wanous *et al.,* 1999).

2.2. BIDDING STRATEGIES PRACTICING IN THE CONSTRUCTION INDUSTRY

Following are some of the bidding strategies practicing in construction industry, highlighted in the existing literature.

Bid Unbalancing: 'Mathematically unbalanced bids' and 'materially unbalanced bids' differ on the basis of proportionating/disproportioning the overheads and profits to the final bid (Christodoulou, 2008). Cattel *et al* (2007) has categorised "bid unbalancing" as 'front-end loading', 'back-end loading' and 'individual rate loading' that vary in terms of the allocation of higher rates in the estimate.

Equally Distributed Mark-up: According to Ariyarathna (2012), this is the easiest way to cover the additional risks associated with conceptual estimates since it adds money to the bid price after which it is equally distributed among every item. The inclusion of the same markup for every item is known as equally distributed mark-up.

Winning Price Criteria: Nawarathne (1998) has pointed out that the price of a large job of similar nature is the criterion used to determine the bid price. For example, the rate for the gross floor area of a similar type of building can be used in future when bidding for projects of this nature. Hence, this historical data is used to predict the bid price with a profit.

Planned Mark-Up: A mark-up factor is introduced to earn profits. However, a smart and aggressive competitor could quickly figure out the popular mark-up factor and, thus, technically knock out other firms by constantly beating the mark-up price of its rivals. Zoysa (1997) has therefore recommended a target outcome and the use of a variable mark-up. Hence, Tiered Mark-up is a variation on the planned mark-up strategy.

High-Low Criteria: According to Zoysa (1997), this strategy determines two critical levels based on the corporate objectives and structure of the contracting organisation. Thus, the bid amount can vary within a range between the two specified ends. The contractor first estimates the project cost, after which he uses the high-low criteria. If he has decided to go ahead based on the above, he then uses another strategy to determine the bid price.

Intuitive Manipulation: According to Nawarathne (1998), this method covers many orthodox strategies ranging from critical decision-making to random guessing of bid price. Here strategic decisions are made based on perceptions or the use of informal information sources. It carries the risk however of corporate collapse due to incorrect decision-making.

Giving Discount after Tender Submission: According to Illukkumbura (1998), the highest bidder can offer a discount and come to the position of the lowest bidder in order to win the bid.

Miscellaneous Section: Some organisations have a separate miscellaneous section in the case of small construction projects where it is not profitable to allocate high overhead (Zoysa, 1997). Hence, the miscellaneous section remains a separate section which can, at the conclusion of the project be added to the company's overall profit where possible.

Diversifying the Jobs in Bidding: Here, the contractor diversifies his bidding in the marketplace (from public to residential to commercial) depending on what he thinks is the most desirable at any given point in time (Nawarathne, 1998).

Bidding for Repetitive Jobs: Some clients tend to give repetitive projects like housing schemes to the same contractor rather than going for competitive tendering and selecting another contractor (Zoysa, 1997). Bidding for such projects thus poses an advantage to the contractor.

Labour Resource Management: This strategy assumes that all contractors can obtain material at the same prices which makes labour costs the only difference between competitors. The strategy is to closely manage workers to minimise labour costs without reducing the fee or unit costs (Nawarathne, 1998).

Standard Fee in Bidding: According to Barr (1990), the contractor has a standard fee below which he is not willing to go. If the contractor feels that he is unable to win the bid with the standard fee, then he decides not to bid. This makes the contractor less competitive.

3. RISKS IN CONSTRUCTION

The construction industry is widely associated with a high degree of risk and uncertainty due to the nature of its operations. The construction industry has furthermore changed rapidly over the past decade with companies now faced with more risk and uncertainty than before (Enshassi *et al*, 2008). Contractors also have to be more competitive in bidding while dealing with the risks connected with bid submission. A project, by definition, is trying to introduce a change, a new production system or way of working, or a new building (Burtonshaw-Gunn, 2009), in which the change entails uncertainty, which in turn introduces a high likelihood of projects being 'blown off course' by a potential future event. Thus, several studies have been conducted to date on the topic amidst growing concern regarding how to manage risk in construction projects (Mak and Wong, 1997). Risk Management (RM) is a management tool that aims at identifying the sources of risk and uncertainty, determining their impact, and developing appropriate responses (Uher, 2003). A systematic approach to RM in the construction industry consists of three main stages: risk identification, risk analysis, and evaluation of and response to risk (Wang *et al*, 2004; Raftery, 2003). Moreover, according to Flanagan and Norman (1993), classification of and attitude to risk are additional steps in the process of RM.

The objectives of risk identification are to identify and categorise risks that could affect the project (Anon., n.d.). Risk classification, in turn, can be categorised under strategic and operational or generic and specific considerations (Kaplan Financial Limited [KFL], 2010). The next step in the process focuses on risk analysis of estimates which allows for the inherent uncertainty of the costs of individual activities or elements within a project when assessing the final cost of the bid (Mak and Wong, 1997). Moreover, though the preceding steps have been carefully considered in the RM process, the decision may vary from one project to another depending on risk attitude. In simple terms, there are three types of organisations: risk favourable, risk averse and risk neutral (KFL, 2010). The RM process concludes with a proposal for risk responses. According to Burtonshaw-Gunn (2009), the options available to respond to risk will be based on one or more of the risk response actions, also known as the '4Ts': Treat, Tolerate, Transfer and Terminate. KFL (2010) has come up with a risk map which takes into consideration the impact of risk and the probability of its occurrence which sums up the RM strategy as available in the literature so far. Risks Associated with Bidding Strategies

According to Illukkumbura (1998), there are three types of risks associated with bidding, namely, risk of losing the bid, risk of under-pricing, and risk of choosing an inappropriate job. Though formal and analytical risk models are available that prescribe how risk should be incorporated into construction bids, Ahmed *et al.* (cited in Laryea and Hughes, 2011) have pointed out that contractors use experience-based mechanisms in approaching risk that are not systematic in nature which, in turn, may result in ineffective RM. According to Laryea and Hughes (2011), it is also the case that risk incorporated in the bid may be excluded at the end to enhance the competitiveness of the bid as the price must reflect other micro-economic factors. Thus, instead of pricing contingencies, it is possible that risk is priced mostly through contractual arrangements to reflect commercial imperatives.

Generally, those who make the lowest bid end up paying more than what the contract is worth in actual fact where the value estimates of rivals remain relatively low. This prospect was initially known as the “winner’s curse” (Wilson, 1969). Contrary to this situation, a well-known adage, according to Drew, Lo and Skitmore (2001), goes that the bidder who makes the most mistakes wins the most number of contracts. Such mistakes may be regarded as random occurrences resulting in either unnecessary additions or omissions that produce high or low bids respectively. Since these types of scenarios too lead to “winner’s curse”, contractors should identify the risks that may lead to ‘winner’s curse” as well as other risks associated with bidding.

3.1. RESEARCH GAP EXPLORATION

This research attempts to bridge the gap that separates research on application of bidding strategies and the research on risk. Although much research exists on the application of bidding strategies and risk as separate phenomena, there is little that explores the risk entailed in bidding strategies and its management. Our study brings together the significant bidding strategies that exist in the industry as mentioned in the literature and identifies their inherent risk component. But risk identification is only the first step in the RM process. It is equally important to identify the risk responsive strategies. Therefore, our study aims to identify the risks inherent in using different bidding strategies and to provide solutions to minimise risk.

However, the scope of the research is limited to identifying and resolving risks related to bidding strategies in the pre-contract stage. Hence, the risks related to bidding strategies during the post-contract stage have not been accounted for in this study. In order to view the topic under study from a wider spectrum and from different angles, the study gathered data from C1-C6 contractors.

4. METHODOLOGY

The study focuses on a topic, i.e., risks inherent in bidding strategies, which constitutes a lacuna in the field of studies related to risk in construction. Hence, much background study was undertaken via an extensive literature survey in order to find a viable research problem and a specific focus for this study.

4.1. DATA COLLECTION

For the purposes of data collection, the study adopted the survey research approach. Semi-structured interviews and a questionnaire survey were conducted among quantity-surveying professionals who have vast experience in the construction tendering process. The semi-structured interviews attempted to identify the risks entailed in bidding strategies and the methods in use to manage. The results of the interview survey were used to formulate the close-ended questions in the questionnaire. The questionnaire survey carried Likert responses to identify the objectives of using bidding strategies, the importance of using bidding strategies, and the extent of using the strategies and their attendant risks in terms of consequences and probability of occurrence. The questionnaire allowed respondents to rate Likelihood and Consequence in 5-number scales. The magnitude of the risk was calculated by multiplying them.

The non-probability sampling technique was used in the data collection. Among the non-probability sampling techniques, ‘Convenience Sampling’, is the most convenient and immediately available sampling method, which was used to select the respondents for the survey. Consequently, the sample size was selected as thirty considering the availability of resources, the aim of the study, the statistical quality required for the study, and the fit between the ideas of the researchers and those of experts in this field. The sample therefore consisted of quantity surveyors from various organisations who are involved in the tendering process.

4.2. DATA ANALYSIS

The qualitative data gathered through semi-structured interviews were analysed using the content analysis technique. The QSR NVivo 2008 computer software was used to simplify the work relating to content analysis. The quantitative data collected through the questionnaire survey were subjected to a statistical analysis using Mean Weighted Rating (MWR), Relative Importance Index (RII) and the One Sample T-test. The formulas for calculating them are given as follows. Moreover, the central tendency assessment was done using statistical tools such as mean, mode and frequency.

The RII technique has been widely used in construction research for measuring attitudes with respect to surveyed variables. Likert scaling was used for ranking questions that have an agreement level. The respondents were required to rate the importance of each factor on a 5-point Likert scale using 1 for not important, 2 for of little importance, 3 for somewhat important, 4 for important and 5 for very important. Then, the relative importance index was computed using the following equation

$$RII = [(W.n) \times 100] / A.N \qquad \text{(Eq: 01)}$$

Where, W = Constant expressing the weighting given to each response, A = The highest weighting, n = The frequency of responses, N = Total number in the responses.

$$MWR = \sum (V_i \times F_i) / n \qquad \text{(Eq: 02)}$$

Where, V_i = Rating of each Factor, F_i = Frequency of Responses, n = Total number of responses

$$t = (\mu_{sample} - \mu_0) / (s / \sqrt{n}) \qquad \text{(Eq: 03)}$$

Where, μ_{sample} = sample mean, μ_o = population mean, s = sample standard deviation, n = sample size

This "t" value was calculated using the IBM SPSS computer software.

However, the methodological limitations were existed in conducting the study. The sample size for the interview survey is not a representative distribution of the population which is limited to five experts. Yet, experts have been selected more specifically in the tendering field with more than 12 years of experience in order to eliminate the probable limitations. Furthermore, the time constraint had narrowed down the data collection to assess the possible risk management strategies. The model assumes that the identified risk factors are mutually exclusive. Although the definitions of risk encompass welcome 'up-side' as well as unwelcome 'down-side' effects, for the purposes of this research, the risk is defined as the 'down-side' consequences of the exposure to economic or financial loss, physical damage, or injury, or delay.

5. DATA ANALYSIS

5.1. RESULTS OF EXPERT INTERVIEW SURVEY

Risk Associated in Bidding Strategies

Since the existing literature was not satisfied in the identification of risks associated with prevalent bidding strategies, semi-structured interviews were conducted among five experts who have more than 12 years of experience in the tendering field to elicit more understanding of risks associated with bidding strategies in Sri Lanka. The empirical data that were subsequently gathered via semi-structured interviews are discussed in this section and presented in Table 1.

Table 1: Risks Associated with Bidding Strategies

Bidding Strategy	**Risks**
Front-End Loading	• Rejection of bid on the basis of 'imbalance' • Unexpected increments in quantity • Increase in performance bond by the client

Bidding Strategy	Risks
	• Request by consultant for rate breakdowns • Requirement for reduction in rates by contractor • Difficulty in maintaining positive cash flow at a latter stage • Possibility of deletion of loaded item • Price fluctuations and lower rates, leading to loss of latter items
Back-End Loading	• Unexpected quantity increments • Price fluctuation affecting end rates • Possibility of omitting loaded items • Possibility of disputes at the end of the project • Possibility of the client giving up or abandoning the project • Impact on cash flow at the initial stage of the project
Individual Rate Loading	• Possibility of lower priced items being increased in quantity • Possibility of higher priced items being decreased in quantity • Incorrect predictions on quantity increments • Possibility of loaded items being omitted due to design changes
Equally Distributed Mark-up	• Possibility of yielding a low profit when a number of sub-contractors are working • Occurrence of cash flow problems • Possibility of actual quantities far exceeding the estimated quantities
Winning Price Criteria	• Non-adjustment of price • Low productivity of labour and equipment than anticipated • Non-availability of projects of similar nature for comparison • Differences between the projects compared
Planned Mark-up	• Non-consideration of value of the project and its duration • Non-adjustment of mark-up to suit the project requirements • Possibility of competitors following the bid pattern
High-Low Criteria	• Possibility of losing jobs that is beyond the two levels • Incorrect estimation of low criteria by contractor • Possibility of going through periods when contractor has no jobs • Possibility of contractor not sticking to market price
Giving Discount after Tender Submission	• Possibility of giving discounts beyond the cost • Possibility of giving discount for under-quoted items • Possibility of damage to reputation due to unethical practices
Miscellaneous Section	• Possibility of mother company taking over and finishing the project • The possibility of project failure and blame is placed on the mother company
Diversifying Jobs in Bidding	• Possibility of occurrence of pricing errors • Possibility of decrease in selected market • Mismatch with pre-qualification criteria • Incurring of additional cost of recruiting expertise and for purchasing of machinery
Bidding for Repetitive Jobs	• Possibility of losing more profitable jobs • Expectation on the part of clients of a higher standard than in the first project • Expectation of discounts by clients and low markups for up-coming projects
Labour Resource Management	• Losses due to low productivity of labour and equipment • Increase in demand for labour while the project is going on • Possibility of in-house labour gang becoming a burden • Inclusion of labour cost without proper plan
Standard Fee in Bidding	• High value of standard fee • Unrecoverable losses • Difficulty in competing or surviving in atmosphere of competition • Reduction in competitiveness
Bidding based on Sub-contractor's Bid	• High price of subcontractors' price and difficulty in winning the bid Errors in sub-contractor pricing

Bidding Strategy	Risks
Intuitive Manipulation	• Probability of failure due to differences in the rates in different places • Post-contract management difficulties due to not keeping contemporary records • Losses due to quantity changes and unforeseeable design, development issues

5.2. *RESULTS OF QUESTIONNAIRE SURVEY*

The questionnaire survey aimed to identify the objectives of using bidding strategies, the extent to which the identified bidding strategies are being used by contractors and the risks associated with each bidding strategy as a quantitative value. 41 questionnaires were distributed while 32 of them were collected in time. Of these, two were rejected due to incompleteness. Therefore, the response rate was 76.9%, which is a satisfactory rate for a survey. The sample represented 63% of main contractors, 27% of sub-contractors and 10% of property developers. Under the ICTAD contractor classification, 40% were classified under C1 or C2, 27% under C3 or C4, 23% as C5 and C6 while the remainder comprised C6 graded contractors.

Objectives of Using Bidding Strategies

Firstly, the objectives of using a bidding strategy were assessed. The participants were allowed to respond according to a 5 rated respondent's scale which ranged from very low (1) to very high (5). The MWR for each factor was computed to deliver an indication of the importance of the factor. Mode was used to identify the most frequent Likert response by the respondents. RII was used to determine the relative ranking of objectives.

Subsequently, 11 objectives were considered in the analysis. Of those, 8 factors were assigned MWR values that were higher than the neutral point 3. It revealed that those 8 factors are either high or are very highly relevant. The 11 factors selected for the analysis were ranked using the RII value. Among those, the highest RII of 84% was held by 'Pursuing a target return on investment'. These results were validated by the central tendency of the data, obtaining the mode value of 4 and 5. Next to the pursuit of a return on investment, 'Continuing the operation of company', 'Ensuring sufficient number of projects in hand', and 'Meeting the expectations of clients and the industry' were the other top five important objectives. However, most of the bidders have given low importance to 'providing a barrier to entry by other firms' which obtained the least RII of 44% and the least MWR value of 2.20.

Degree of Importance of Bidding Strategies

In order to determine the degree of importance of bidding strategies, the 5-rated Likert scale, which ranged from very low importance (1) to very high importance (5), was included in the questionnaire. The above-mentioned statistical tools were used for the same function of analysis. 15 bidding strategies extracted from the literature survey were considered in the analysis. Nine bidding strategies out of the 15 were assigned MWR values higher than the neutral point 3. The highest RII of 74% was gained by 'Bidding for repetitive jobs' while the least RII of 36% was gained by 'Back-end loading'. Similarly, the MWR results were endorsed by the mode values, obtaining the weightage of 4 and 1 for the highest and lowest ranked strategies respectively. Moreover, 'High-Low Criteria' and 'Sub-contractors' bid-based bidding' received equal importance at 69.33% and were ranked as the second most important strategy.

Extent of Using Bidding Strategies

The questionnaire survey was further extended to identify the extent to which bidding strategies are used in the Sri Lankan construction industry. Responses were coded according to the 5-rated Likert scale which ranged from very low used (1) to very high used (5). The 'Equally distributed mark-up' strategy ranked as the most extensively used strategy gaining an RII value of 76.67%. Similarly, by obtaining the mode value of responses as 5, it became the application most used in Sri Lankan bidding practice. 'Front- end loading' and 'individual rate loading' ranked as a close second and third by gaining the RII value of 74% and 70.67% respectively. On the other hand, 6 bidding strategies were assigned MWR values lower than the neutral point 3. They are 'Winning price criteria', 'Diversifying jobs in bidding', 'Miscellaneous section', 'Intuitive manipulation', 'Labour resource management' and 'Back-end loading,' which appear to be used less in Sri Lankan practice.

Risk of Using Bidding Strategies

The Likert respondent's scale which ranges from improbable (1) to very likely (5) was used to gather data on the prevalence of the various bidding strategies among contractors in Sri Lanka. Similarly, consequences were rated on the scale ranging from Negligible (1) to Disastrous (5). Consequently, risk was quantified by multiplying likelihood and consequence. Since more than one risk is involved in a particular bidding strategy, the mean value was computed to derive the value of various risks associated with the bidding strategy because the mean of all risk factors is a much better value than the summation of the risks. Further, T-statistics were calculated using IBM SPSS software for the purpose of comparison of the different statistical measures.

A slight difference is noticed in ranks calculated with respect to the mean and T-statistic where riskiness is the lowest for 'Miscellaneous section' under the mean value ranking and 'Bidding for repetitive jobs' under the T-statistic ranking. However, both measures reveal the highest risk to be 'Intuitive manipulation'. 'Equally distributed mark-up', 'Front-end loading' and 'High-low criteria', on the other hand, are identified as low-risk strategies accordingly. In contrast, 'Back-end loading', 'Labour resource management' and 'Individual rate loading' are the other high-risk bidding strategies as Table 2 shows.

Table 2: Risk Values of Bidding Strategies

Bidding Strategy	Mean	Rank	t-statistic	Rank	
Intuitive manipulation	17.77	1	20.394	1	High Risk
Back end loading	15.89	4	9.348	2	
Labour resource management	16.57	2	8.403	3	
Individual rate loading	15.99	3	5.361	4	
Winning price criteria	14.45	5	3.972	5	
Planned mark-up	14.24	6	3.497	6	
Discount after tender submission	14.14	7	1.821	7	
Standard fee in bidding	12.33	8	-1.697	8	
Subcontractors' bids based	9.42	10	-6.003	9	
Diversify the jobs in bidding	10.27	9	-9.264	10	
Miscellaneous section	6.60	15	-12.469	11	
High-low criteria	8.86	12	-15.275	12	
Front end loading	9.24	11	-15.802	13	
Equally distributed mark-up	7.67	14	-21.677	14	
Bid for repetitive jobs	7.69	13	-24.364	15	Low Risk

Methods of Managing Risk

The RM process ends with the conveyance of the RM strategies. The results derived from the open ended questions in questionnaire survey are tabulated in Table 3.

Table 3: Methods of Managing Risks of Bidding Strategies

Bidding Strategy	Method of Managing Risk
Front-End Loading	• Only the items above an overall justifiable level should be front-loaded • Deciding on an optimum range of loading that is not identified in the Perato Curve • Proper management of the cash received initially
Back-End Loading	• Avoiding back-loading in any way
Individual Rate Loading	• Re-checking the estimated quantities before setting the rates. Depending not only on the tender drawings, but also on specifications, contractor's own method statement, details gathered during the site visits, soil report, previous experience, etc.
Equally Distributed Mark-up	• Mark-up is HOH, SOH and profit. SOH are often given in the preliminary bill. Hence, calculating carefully and holistically the head office contribution of the total project for the total duration • Use of different mark-ups where necessary

Bidding Strategy	Method of Managing Risk
Winning Price Criteria	• Calculating the basic cost accurately • Taking into consideration location and economical, technical, commercial, etc., factors and making necessary price adjustments for a rational bid decision.
Planned Mark-up	• Considering location, economic, technical, commercial, etc., factors and making necessary price adjustments for a rational bid decision. • Deducting the portion of SOH covered by preliminaries related to each project from the planned mark-up
High-Low Criteria	• Considering location, and economic, technical, commercial, etc., factors and making necessary price adjustments for a rational bid decision • Being flexible in changing the limits to get profitable jobs beyond the two levels
Giving Discount after Tender Submission	• Revisiting the pricing strategy and seeing how far the contractor can go down in terms of the amount he would lose in the anticipated profit
Miscellaneous Section	• Monitoring the subsidiary company's activities • Checking whether the miscellaneous section can handle the job before taking the decision as any failure would harm the goodwill or reputation of the company.
Diversifying Jobs in Bidding	• Balanced allocation of working capital after considering every sector
Bidding for Repetitive Jobs	• Maintaining good relations with clients • Making sure that there are appropriate provisions for rate adjustments in the case of future projects
Labour Resource Management	• Considering other factors as well, such as materials, plant and tools as a contractor's technical approach would differ from site to site
Standard Fee in Bidding	• Matching standard fee with the project requirements and selecting only appropriate jobs for bidding as this would not be applicable to all projects
Bidding based on Sub-contractor's Bid	• Obtaining quotations from one or two reliable sub-contractors • Checking sub-contractor's prices for accuracy and appropriateness before using them. • Going for back to back agreements • Obtaining a high-performance bond • Transferring full liquidated damages (LD) to the sub-contractor
Intuitive Manipulation	• Making sure of an estimated net cost • Using past experience and the analytical mind in decision making

6. CONCEPTUAL MODEL OF MINIMISING RISKS OF BIDDING STRATEGIES

Finally, a conceptual model was developed summarising all the survey findings in a single illustration as shown in Figure 1. The web illustration of different risks and responses associated with bidding strategies allows users to act rationally in the bidding process in order to gain competitive advantage over rivals.

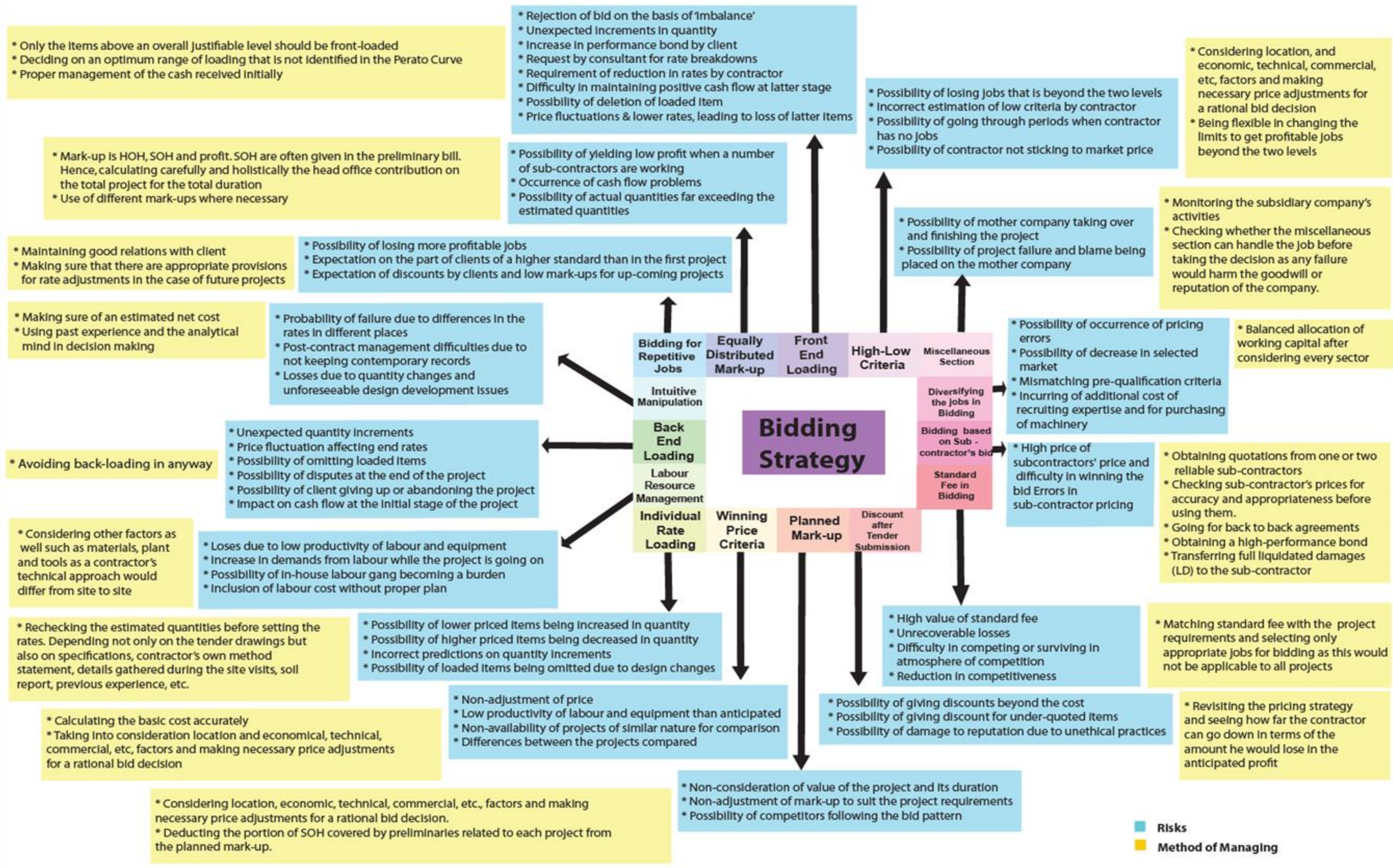

Figure 1: Conceptual Model of Minimising Risks of Bidding Strategies

7. CONCLUSIONS

The complexity and dynamic nature of the construction industry has made construction-bidding complicated and competitive. Thus, contractors have come to use their own strategies to ensure their survival and development. While having to bid competitively, contractors, at the same time, deal with risks and uncertainties associated with bidding which they find difficult to foresee. The present study aimed at identifying the risks associated with the different bidding strategies used by contractors in Sri Lanka and providing solutions to minimise such risks.

A larger number of bidding strategies were identified in the literature of which 15 bidding strategies were extracted. They are front-end loading, back-end loading, individual rate loading, equally distributed mark-up, planned mark-up, standard fee in bidding, high-low criteria, giving discount after tender submission, bidding for repetitive jobs, winning price criteria, diversifying the jobs in bidding, miscellaneous section, labour resource management, bidding based on subcontractors' bids and intuitive manipulation.

Table 1 tabulates the different risk factors of each bidding strategy that have been identified through the semi-structured interviews. The results of the questionnaire revealed that contractors use bidding strategies mainly to accomplish the objective of getting a target return on investment. Additionally, contractors aim at the continuation of the operation and ensuring a sufficient number of projects in hand. The bidding strategies were also ranked according to their importance which showed the “Equally distributed mark-up strategy” to rank as the topmost strategy used extensively by contractors. “Front-end loading” and “Individual rate loading “ranked second and third. In contrast, ”Winning price criteria”, “Diversifying jobs in bidding”, “Miscellaneous section”, “Intuitive manipulation”, “Labour resource management” and “Back-end loading “are not as much used among Sri Lankan contractors. The questionnaire survey also attempted at quantifying the risks. It showed the “Bidding for repetitive jobs”, “Equally distributed mark-up”, and “Front-end loading” to be low-risk bidding strategies while “Intuitive manipulation”, “Back-end loading” and “Labour resource management” as high-risk bidding strategies. The next crucial objective was RM. Table 3 has identified and tabulated the ways of managing the risks of each bidding strategy. Moreover, a conceptual model has summarised all the survey findings in a single illustration including different risks and responses associated with bidding strategies.

The present study provides a guide for construction contractors to select the best suited bidding strategy bearing in mind the inherent risk component of each strategy. Further, the research is is sensitive to the different risk attitudes of the bidders. If a bidder is risk averse, he is then directed to low-risk bidding strategies. On the other hand, if a bidder is risk favourable, such a person can use high risk strategies in full knowledge of the inherent risk component as well as the risk responsive strategies. Finally, the study recommends the investigation of the risk of using bidding strategies from the client’s perspective for the purpose of delivering the best value for money to the client.

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ROLE OF MULTI-DISCIPLINARY PROJECT STUDIES IN PROMOTING SUSTAINABILITY WITHIN THE BUILT ENVIRONMENT DEGREE PROGRAMMES

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ABSTRACT

The need to contribute to the sustainability agenda is increasingly becoming a key requisite for both academics and practitioners in the built environment disciplines. The triple bottom line indicators of sustainability involve the consideration and collative optimisation of environmental, social and economic aspects of projects. Therefore, it is of vital importance that the current and future built environment professionals are able to ensure that they provide sustainable built environment solutions. Higher education institutions which offer built environment degree programmes use different approaches to achieve this requirement. Multi-Disciplinary Project Studies (MDPs) have been identified as a way of imparting such knowledge and practices for the built environment students.

The principal aim of this paper is to discuss two approaches in delivering multi-disciplinary projected studies adopted in two higher education organisations in the UK. Firstly, the paper aims to identify the key components of the sustainability agenda, while explaining how the delivery of multi-disciplinary project modules can be contributed to it. Secondly, it discusses two different approaches for multi-disciplinary projects and analyses how each approach contributes to imparting the skills and knowledge to develop sustainable built environment solutions. Finally the opportunities opened up challenges encountered in both models, and the implications to teaching and the industry practices are discussed. A literature review on pedagogical teaching and participant observations were the main methods used to collect data. The preliminary findings indicate the positive role of the MDPs in contributing to the sustainability agenda. Further research and innovation is required to overcome the challenges of organisation and assessment, and greater integration with Building Information Modelling (BIM).

Keywords: *Built Environment; Collaboration; Higher Education; Multi-Disciplinary Projects; Sustainability; Teaching.*

1. INTRODUCTION

The need to contribute to the sustainability agenda is increasingly becoming a key requisite for both academics and practitioners in the built environment disciplines. Locke *et al* (2009) points out that the United Nations Decade of Education for Sustainable Development (2005-2014) has highlighted the importance and the vital need to incorporate sustainable development within teaching and learning. As a result, higher education institutions (HEIs) are increasingly focusing on sustainable development as a one of significant components in their activities, while the Higher Education Funding Council for England (HEFCE) has adopted this approach and outlined a range of performance targets for universities.

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The triple bottom line indicators of sustainability involve the consideration and collative optimisation of environmental, social and economic aspects of projects. Therefore, it is of vital importance that the current and future built environment professionals are able to ensure that they provide sustainable built environment solutions. Higher education institutions which offer built environment degree programmes use different approaches to achieve this requirement. Multi-Disciplinary Project Studies (MDPs) have been identified as a way of imparting such knowledge and practices for the built environment students.

This paper focuses on two different approaches for conducting multi-disciplinary projects in two higher education institutions in the UK, while explaining how those approaches fit with the sustainability agenda.

2. AIM AND OBJECTIVES

The principal aim of this paper is to discuss two approaches in delivering multi-disciplinary projected studies adopted in two higher education organisations in the UK. Firstly, the paper aims to identify the key components of the sustainability agenda, while explaining how the delivery of multi-disciplinary project modules can be contributed to it. Secondly, it discusses two different approaches for multi-disciplinary projects and analyses how each approach contributes to imparting the skills and knowledge to develop sustainable built environment solutions. Finally the opportunities opened up challenges encountered in both models, and the implications to teaching and the industry practices are discussed.

3. RESEARCH METHODOLOGY

Several research methods have been used in preparation of this paper. Literature reviewed on sustainable development and higher education sector's contribution to the sustainable development enabled the establishment of the background and the rationale for the paper. In addition the teaching and learning literature strengthened the discussion on the opportunities, challenges and implications section. Participant observations of multi-disciplinary project modules paved the way for obtaining the empirical data for this paper.

4. FACTORS THAT NEED TO BE CONSIDERED TO FULFIL THE SUSTAINABILITY AGENDA

The Rio Declaration highlighted the importance of collaborative efforts from the teaching, research and business sectors in achieving the overall sustainability agenda. Leadership, Learning and Teaching, Practice within HEI, partnership and community working, and research are indicated as avenues through which higher education sector can respond to the challenge (Welsh HE Institutional Group, 2010). According to Sterling (2011) education for sustainable development can be broadly termed as education, teaching and learning that appear to be required if we are concerned about ensuring social, economic and ecological well-being, now and into the future. The UK's Higher Education Academy (HEA) is contributing to the suitability agenda by aiming to help higher education institutions in the development of sustainability literate graduates who have the skills, knowledge and experience to contribute to an environmentally and ethically responsible society. The HEA also acknowledges that in attempting to meet this challenge, the traditional pedagogies may be challenged, and requires a multi-disciplinary partnership approach across and between institutions (Higher Education Academy UK, 2014). There is evidently a need for stronger commitment to implement Education for Sustainable Development (ESD) and to implement the changes needed to achieve the performance targets set out by HEFCE (Locke *et al*, 2009).

Sterling (2011) noted that Education for sustainable development is flourishing in universities where it is embedded in the curriculum, part of the culture of the university, seen in relation to (rather than separate from) other agendas such as employability, internationalisation and enterprise, linked to sustainability initiatives and learning in the wider community. Furthermore he points out that the wider context and employment where there is a need for HE to both respond to and help shape real-world conditions, policy and mandate, the expectations from funding councils, and increasingly, from HEI senior managers, education and quality, where quality and innovative teaching and learning as some of the rationale for engaging in education for sustainable development.

The national curriculum highlights the need to educating students to think creatively and critically to solve problems and to make a difference (Department for Education and Employment 1999 in Wade 2002).

Education must also support the ethos of sustainability as students' attitudes to the environment are difficult to change (Wade, 2002; Locke *et al*, 2009)

In broad terms, sustainability focuses on three main themes; social; economic and environmental accountabilities, which are often referred to as being the 'triple bottom line' (Hall, 2011). Sustainable development encompass social progress, environmental protection, improved use of resources, employment and economic growth, and economic stability. The Built Environment (BE) and construction related work involve a series of team based, integrated multi-disciplinary activities. The construction industry has been blamed for its fragmented nature and the lack of integration in its processes and practices for a considerable amount of time. Therefore, group based problem-solving assessments within the BE curriculum is always encouraged (Morgan *et al*., 2004, Lam 2008) to ensure that students are acquiring required skills before they enter into the construction industry. In the above light, multi-disciplinary projects (MDPs) are seen as a way of imparting the knowledge of sustainability. The MDPs provides the opportunity to integrate the various built environment disciplines at the higher education level. As such technical, economics and managerial (people) skills which are essential in the quest for developing sustainable solutions can be incorporated in a real-life setting.

5. APPROACHES FOR MULTI-DISCIPLINARY PROJECT MODULES

Built Environment (BE) and construction related work usually involve multidisciplinary activities to complete a project. Due to the involvement of team work in most of the BE related projects, literature within the BE emphasis the need of group based, problem-solving assessments (Lam, 2008; Morgan *et al*., 2004) so that students can train to acquire skills related to team work. Group based assessments are promoted due to their advantages such as students gaining experience of working in teams, students can discuss and learn from their peers, students finding group work as more enjoyable and interesting (Miller *et al*., 1998; Garvin *et al*., 1995), appreciation of different opinions and views of peers (Collier, 1986). In this paper, two approaches used in two UK higher education institutions are presented and implications discussed.

5.1. THE THROUGH-SEMESTER APPROACH

In this approach, a module titled Multi-Disciplinary Projects (MDP) is conducted involving undergraduate students from disciplines namely Construction Project Management, Property Management and Investment, Quantity Surveying, Building Surveying and Architectural Design Technology). Students engage in the project activity during a full semester (approx. 12 weeks). However, the allocated time for this in a week is approximately 3 hours. Students are provided with a real-life problem based scenario, often a project benefiting the community, and the students are required to find solutions by working in groups. Miller *et al*. (1998) highly recommend the use of real cases from industry for group based assessments. As the scenario for the assessment was based on the real-life case, module delivery was done through a series of guest lecturers from the industry. Questions and answer sessions are also introduced during the module with the industry practitioners. This module has always been intended as the platform to provide the students with the opportunity to allow working in multidisciplinary groups mimicking the multi-disciplinary nature of construction projects (Keraminiyage, 2013). Expected outcomes from the students are designs according to the client's brief, demonstration of consideration of theories and principles thought in other modules, cost estimates including whole life costs, environmental considerations, and development appraisals providing guidance on funding arrangements. The overall submission forms a considerable portion of the planning application that the particular community project client requires to submit to the local authority to obtain planning permission. Keraminiyage (2013) observes that from the very beginning, the client is expected to work closely with the students and generally there would be a live question and answer session organised as a part of the module, so that the students can get clarifications to any of their queries directly from the client. In addition, few site visits would generally be organised, so that the students can get a feeling about the actual project context. Mode of delivery for this module is largely through specialised guest lectures from the industry experts and directed group activities. Industry experts covering all aspects of the project (architectural, quantity surveying, etc.) are invited and agreed upon, at the beginning of the semester, to deliver guest lectures.

The assessment requires the students to submit a consist of a project execution plan, an interim group presentation and a final group presentation assessed on a group basis and marks adjusted for individual members based on an effort log scoring system by peers, and in the final week of the semester an individual reflective commentary about the individual and group contributions to the project (Keraminiyage, 2013). The assessment team also comprises of a group of tutors representing different disciplines. The assessment is structured in such a way that coordination and input are required to complete the assessment. Further, some aspects of the assessments (mainly the presentations done by the students) were assessed with the involvement of industry practitioners.

5.2. THE PROJECT WEEK APPROACH

In this approach, the students design and construct a building or a related infrastructure on an experimental construction site (http://www.constructionarium.co.uk/). Students are required to be resident within the construction for the entire project duration. Two such project weeks are conducted per year. The teams are made up of members from different construction industry disciplines such as Quantity Surveying, Building Surveying, Construction Management, Architecture and Civil Engineering. Students are required to design and construct structures within controlled cost, time and quality targets. Refer http://www.youtube.com/watch?v=zWGTtO6KkyI for further information.

Teams formed by the academic staff. The assessment brief requires the students to design and construct an already existing structure but at a much lesser scale. The students interact closely with practising professionals. The industry professionals belonging to the various subject disciplines are also involved in the assessment and feedback process.

Whilst many education theorists, academics, construction professionals, and students themselves point out many advantages of such project work built-in modules, there are a number of challenges that can be identified within the Multi-Disciplinary Projects (MDP). These challenges mainly stem from the academic practice point of view, and the successful addressing and management of these challenges are a key determinant of success when seen from a higher education teaching practice performance perspective.

6. DISCUSSION: OPPORTUNITIES, CHALLENGES AND IMPLICATIONS

MDPs provide an excellent opportunity to facilitate problem based learning and also to provide formative feedback. Wood (2003) pointed out that teamwork, chairing a group, listening, recording, cooperation, respect for colleagues' views, critical evaluation of literature, self-directed learning and use of resources and presentation skills as generic skills and attitudes fostered by problem based learning. These assessments are always promoted within the curriculum due to their advantages such as team work, learning from the peers, students enjoying their work (Miller *et al*., 1998); appreciation of peer opinions (Collier and Clarke 1986), and encouraging student autonomy (Freeman 1995, Biggs 2001). MDPs in this context allow the students to gain most of these, thereby giving them the much needed employability skills. The module helps to develop students' knowledge and understanding about the subject due to rich feedback received from academics, professionals and clients; interactive and deep learning (Biggs 2003).

Moreover, different types of assessment methods used for MDPs further contribute to creating a rich assessment and feedback strategy. In addition, feedback for MDPs is offered by different parties ranging from peers, academics, professionals etc. Furthermore, these modules provide such opportunities for professionals and clients within the built environment sector to contribute to the assessment and feedback at the university level in inspiring students to believe that the classroom activities can actually be made to work in the real world. Therefore, MDPs create a good opportunity to revisit and further enhance the role that the various regulatory bodies such as Higher Education Academy (HEA), Royal Institution of Chartered Surveyors (RICS), Royal Institute of British Architects (RIBA), and the Institute of Civil Engineers (ICE) etc. could play a vital role in enhancing the teaching and learning process of the students in the BE sector, especially with regard to proving them with key professional knowledge and skills.

However, the MDPs present many challenges in a multitude of ways. MDPs are complex in nature due to number of reasons. The MDPs enrol a diverse group of students. The involvement of students from different disciplines within the BE sector sometimes create an "intra-discipline blame culture" as oppose to "appreciation" of other discipline's work. Furthermore, as in any student cohort, the students involved in this module are diverse based on mode of study (full-time, part-time division); experience; maturity; expectations etc.

Different types of assessment methods (written reports, verbal presentations, questions and answer sessions, design critiques, field observations, reflective commentaries etc) are used for MDPs presents challenges in terms of timing of assessments, managing student and staff workload, and the extent of feedback given for assessments. Furthermore, capturing feedback given by different parties in diverse formats (written / verbal / rubric / virtual workspace) and bringing them to a common platform has been identified as an issue which has hindered the effectiveness of the rich feedback given during the MDP process.

Team work is an integral part of MDPs. However, when it comes to allocation of marks, students may not always find the outcomes satisfactory always. For example "free riders" (Brooks and Ammons 2003); lack of fair allocation of marks based on individual contributions (Heathfield 1999); impact of weak students on high performing students (Kember *et al*., 1996); and also inconsistent marking of tutors (Lam 2008) are some of them. These issues can be further complicated when combined with the involvement of large number of students; diversity of the student population (full-time, part-time, experienced, international); number of assessment and feedback (A and F) methods etc. In many instances peer reviews can be used to address "free riders" (those who doesn't contribute to group work) and "sucker effect" on better performing students (good students not performing due to "free riders" of the group hence producing less quality output).

Another challenge encountered in the MDPs is the role and the attitude of the tutors. Problem based learning creates environments where not only the students but the tutors learn as well. However, effective utilisation and benefit realisation of such opportunities occur only when the tutors dedicate fully. The various performance indicators that academics in the higher education required to gain (i.e. research, enterprise activities) sometimes results in MDPs being seen as extremely resource intensive.

Therefore, the assessment and feedback framework need to be developed for designing, delivering and managing MDP assessments whilst achieving the academic rigour, integrity and needed compliance with Quality Assurance purposes. Furthermore, appropriate mechanisms are required to develop to compile the various forms of feedback from MDPs to a single platform, which will facilitate the tutors to evaluate students performances based on the comments given at different stages of the module. This of course ensures the academics to give appropriate marks for the students on an evidence-based, rigorous process. Having said that it is expected that those mechanisms would help to improve the effectiveness of the formative feedback given, which will in turn further improve the students' work to the required standards. Also, given that there will be a number of examiners contributing to assessment; and they are expected to help achieving consistency by improving the moderation / internal verification process.

Other problems include lack of performance of some students resulted in whole team struggling to complete the task, delay in carrying out some discipline specific task making an impact on other disciplines to complete their tasks (for example, when ADT students do not prepare drawing on time, this had a knock-on effect on the QS students to cost the project) and the challenge of managing a large group of students in terms of delivery, assessment and feedback. Keraminiyage (2013) reported significant benefits that the MDP module brings to the community. The local community benefits from access to free expert advice and guidance on their construction projects including many alternative solutions addressing their requirement, thereby giving them a wide choice for selection. It also acts as a conduit for the industry to engage with community projects, thereby contributing to the corporate social responsibility item in their agenda. Academia-Industry collaboration is also enhanced.

Students' learning and satisfaction is a key priority in higher education. In this regard assessment and feedback for this module plays a key role. As feedback is provided by a variety of sources including the professional practitioners within the Built Environment (BE) sector, students value such feedback as they come from the real life practitioners. Therefore, the student learning experience is improved with appropriate feedback discussions with professional. Therefore the assessment and feedback strategy should consider to maximise the real life experience obtained from the stakeholders (client, professional employers), which will improve student learning experience and build up their confidence is managing actual construction project when they are graduated.

This discussion emphasises the real need of introducing MDP projects within the BE sector. The success and the impact of this study will be measured during the project lifecycle through different performance indicators (e.g. World of Work skills). The student engagement will be given the somewhat high prominence. The informal observations by tutors and steering group on MDPs will be used to study the group cohesiveness and synergy which of these dimensions of student engagement are not readily quantifiable but identified as highly important in higher education agendas.

Surpless and Bushey (2012) offer some of the good practice suggestions. These include planning the assessment framework at the early stages of the project brief development, maximising the number and type of assessments to enrich the learning environment (within the resource constraints of the organisation) and build in feedback mechanisms including formative evaluation and finding ways to integrate assessment of project activities with existing course / institutional tools.

Furthermore, as a future action it is an absolute necessity to incorporate Building Information Modelling (BIM) with the Multi-Disciplinary Project modules. BIM can be seen as the technical and managerial platform powered by the advent of Information and Communication Technologies (ICT) to manage design and construction of built facilities. It facilitates and encourages multi-disciplinary working. With the UK government's directive to use BIM on all government projects by the year 2016, the above mentioned combination of BIM and MDP will create an attractive learning and teaching environment with powerful and user-friendly tools to provide both formative and summative feedback.

7. CONCLUSIONS

The need to impart knowledge and skills which contribute to the overall sustainability agenda has been well recognised. High level policy documents encourage the higher education sector as well the built environment sector to play their part in this regard. Given the fragmented nature of the construction industry, the Multi-Disciplinary Project approach in built environment higher education programmes provides an opportunity to make a significant contribution towards the sustainability agenda.

Higher education institutions employ various approaches to conduct multi-disciplinary projects in their built environment programmes. This paper presented two such approaches, namely the through-semester approach and the project week approach. Both approaches provide strong opportunities to impart knowledge and skills required from the built environment perspective to contribute to the sustainability agenda. The strong community engagement and multi-point assessment are key features of the through-semester approach. The construction site based nature, and the rapid assessment and feedback is a strong feature in the project week approach. Both approaches are well received by the students and the employers, in spite of the challenges encountered in terms of organisation and assessment.

As Building Information Modelling (BIM) becomes a key part of the future construction industry, the Multi-Disciplinary Project based nature of working will be a key requisite. Therefore, it is highly likely that the design and delivery of built environment in the future will be founded on Multi-Disciplinary approaches. Given the impact that any negative student experience is having on performance measures such as the National Student Survey (NSS), further research and innovation is required ensure that higher education institutes are able to strengthen their ability to provide the students a with positive multi-disciplinary learning experience.

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STRATEGIES TO RECRUIT AND RETAIN PROFESSIONAL QUANTITY SURVEYORS IN THE PUBLIC SECTOR CONSTRUCTION ORGANISATIONS

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ABSTRACT

Construction industry has a direct link to the country's economy and development. It is the Quantity Surveyor's (QS) responsibility to ensure that the resources in the construction industry are utilised to the best advantage of the society by providing financial management for project and cost consultancy to the client during the whole construction process. Hence Quantity Surveying (QS) profession is significantly important for any building or civil engineering project. Due to the dynamic nature of the construction industry, an incessant battle has to be competed with the constraints of time, cost and quality. In this scenario, QS has the responsibility to utilise the monetary fund very efficiently and effectively to gain the optimum value for money without having the risk of losing control of money. Therefore, QSs are working as cost planners, cost controllers and cost managers. Their role and the practices are expanding day by day and the industry demands for QSs with variety of experience, distinctive competencies and skills. At present, a precarious shortage of QS professionals can be often evidenced in Sri Lankan construction industry. The tendency of having the aforementioned shortage is tremendously high in the public sector projects due to the extreme governmental influence. Moreover, the probability of government QS professionals leaving work places and join the public sector is highly increased in past few decades. Since QSs are one of the human resource inputs to the construction industry, it can be understood that employee turnover will barricade the sustainable construction practice in public sector by failing to preserve the human resource for the future. Therefore, the aim of this study was to investigate the strategies to recruit and retain professional QSs in public sector organisations.

The survey approach was used to investigate the research problem and questionnaires and semi-structured interviews were used as the data collection techniques. Data was collected from two samples; QSs working in public sector and Human Resource Managers (HRM) in public sector construction organisations respectively. Binomial test, Relative Importance Index (RII) and few simple arithmetic formulas were used to analyse quantitative data and content analysis was used to analyse qualitative data. According to the research findings, QSs in public sector are reluctant to retain due to low salary packages, less opportunity to develop their career and insufficient work under their scope. According to the binomial test, the majority of QSs think that proper human resource management will be a good solution to overcome this shortage. According to the perspective of human resource managers, although they have realised the problem, they have to implement the plans and strategies according to the government rules and regulations. As the final outcome of the research, a framework was developed to recruit and retain more QSs in public sector construction organisations.

Keywords: *Human Resource Management; Public Sector; Quantity Surveyors; Recruitment; Retention.*

1. BACKGROUND

Construction industry is a vital part of the economy in any country (Senarathne and Sabesan, 2008). According to ICRA Management Consulting Services [ICRAMCS] (2011), the construction industry occupies an important position in the Sri Lankan economy as in any developing economy. Further, it is evidenced that the construction industry received a sudden rise after the civil war in Sri Lanka (ICRAMCS, 2011). Senarathne and Sabesan (2008) explained that construction is often used as a socio-economic indicator of a country and

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therefore, it is indispensable in the process of socio-economic development. Since, construction sector carries a vital importance in socio-economic development, its success is highly required, hence, the inputs to the industry should be fully utilised (Hendrickson 1998). According to Loosemore *et al*. (2003), human resource is the most valuable asset in construction industry since it is relatively low-tech yet more labour-intensive. Therefore, attracting, retaining and developing the talented employees will be the key to the successful construction (Loosemore *et al*., 2003).

Public sector currently obtains more consideration and increasing pressure to obtain value for money from each and every service they use and the projects they deliver (Ferdinando, 2012). Hence, the government is required to find the best suited method for achieving their target of having value for money while providing exact facility required by the general public (Jayasena, 2009). Moreover, public sector projects focuses on values such as value for money, transparency and accountability rather than the economic benefits such as profits (Weerawardhana, 2010). Hence, an effective financial management is essential for public sector (Rahmani, 2011). Canadian Institute of Quantity Surveyors (2012) ensured that the best profession for effective financial management and cost control is Quantity Surveying. Moreover, the skills such as project management and value management also help public clients to achieve their needs and expectations (Seeley, 1997). As per the findings of Rahmani (2011), cash flow and credit are dominant factors for public clients so that effective project management is indispensable, therefore, completion of project on predetermined time and within client's budget is essential since public sector most probably deals with the large scaled projects and intensive capital. Hence, QSs have a prior demand in the public sector in order to provide financial advices.

The construction industry everywhere faces difficulties, problems and challenges (Ofori, 2010). Although there is a growth in Sri Lankan construction industry, as a developing country, there are challenges to overcome in this industry as well (ICRAMCS, 2011). ICRAMCS (2011) found that shortage of professional staff is a key issue in Sri Lankan construction industry and it can be highly seen in public sector. According to the SWOT Analysis done by ICRAMCS (2011), it was identified that lack of skilled workers is a weakness of the construction industry as well as the migration of skilled professionals to the Middle East is considered as a threat to the Sri Lankan construction industry. This scenario is completely applicable to the QS profession in public sector construction of Sri Lanka since there is a high tendency of public sector QSs migrate to other countries and walk into private sector due to low salaries, fewer opportunities and poor training and development (Senarathne and Sabesan, 2008).

This research paper addresses about the shortage of professional QSs in the public sector construction organisations. Key issues of construction industry, involvement of the public sector to the whole construction industry, reasons for the shortage of QSs in the public sector, obstacles to recruit and retain QSs in public sector organisations, relationship between Human Resource (HR) functions and the shortage of QSs are discussed through the research. A framework is developed to recruit and retain QSs in the public sector construction organisations as the final outcome. The aim of the study is to investigate the strategies to recruit and retain professional QSs in public sector organisations. In order to achieve the aforementioned aim, following research questions were identified.

- What is the demand for professional QSs?
- What are the reasons for the shortage of professional QSs in public sector?
- What are the obstacles and hindrances to recruit and retain professional QSs in public sector?
- What is the role of Human Resource Managers and their responsibilities in retaining professional QSs in the public sector?
- What is the identical process to recruit and retain more professional QSs in public sector?

2. LITERATURE REVIEW

2.1. CONSTRUCTION INDUSTRY

Construction industry is a large, active and complex industry (Behm, 2008). It is a segment of commercial activity which creates, modify, repair, and demolish a building, civil engineering works, and other similar structures (Faizal, 2010). Further to author, the development of construction industry grows swiftly as well as a triangular connection between cost, quality, and time is maintained to improve benefits. Contribution of the construction industry to the economy can be seen through various types of concepts. Value addition, trade balance, investment, employment and sectorial linkages are some of parameters which reflect that contribution. Unlike other sectors, construction industry has their unique characteristics (Senarathne and Sabesan, 2008) such as the product is normally manufactured on the client's premises, many of its projects are one-off designs in the absence of a property model, traditional arrangement separates design from manufacture, construction activities are affected by the changing of weather and subject to wider swings of activities than most other industries. Moreover, Ofori (2010) stated that the importance of taking measures to improve the performance of the construction industry has now been recognised in several countries at various levels of socio-economic development.

In Sri Lanka, both private and public sector involve in construction industry (Kariyawasm, 1997; Weddikkara and Devapriya, 2005). Public sector construction organisations are basically divided into two categories called fully government and semi government. In both arrangements, public sector acts as both Contractor and Consultant. Public sector of Sri Lankan construction industry often face challenges such as high raw-material costs, lack of availability of funds, material shortages, shortage of skilled workers and professionals, delays in land acquisition and frequent changes in regulations particularly in development control and approval processes (ICRAMCS, 2011). According to Levy (2000), the shortage of both skilled trades-people and experienced managers will place more weightage on the need to enhance the quality and quantity of training in order to manufacture more effective and productive workers.

2.2. PROFESSION OF QUANTITY SURVEYING

Quantity Surveying is a dynamic process which has Two Hundred and Fifty years of history (Kariyawasam, 1997). QS has the responsibility to manage financial and contractual issues of the construction process (Senarathne and Sabesan, 2008). According to Pheng and Ming (1997), the QSs should foresee the task through the feasibility stage to the completion of the project. Being one of the key professional experts in the construction sector, QSs have the utmost responsibility to address the budget and its related functions (Senarathne and Sabesan, 2008). Therefore, QSs plays a vital role in a construction project. In the past, the role of QS was defined to ensure that the resources of the construction industry are utilised to the best advantage of the society (Pheng and Ming, 1997).

With the identification of new opportunities in the twenty first century, QSs began to explore new potential roles for their services (Pathirage and Amaratunga, 2006). It is a must for the QSs to remain up-to-date in terms of their skills, knowledge, talents and competency in order to face the forthcoming challenges and to find the solutions that would enable the successful completion of the projects (Bucknail, 2012). The key clients of public sector are mostly government organisations. The public service of the QSs includes employment in government departments and agencies, local authorities and some statutory bodies. The QS's main responsibility in public sector is to control the public money and monitoring the way that it is being spent (Rahmani, 2011).

According to Association of South African Quantity Surveyors [ASAQS] (2012), efficiency, innovation and best practices in the private sector are creating a concentration of adequately skilled QSs, while the public sector is struggling with a lack of skills, especially at municipal level. Moodley (2012) argued that, the public sector often fails to attract well-qualified and mature minds and sometimes settles for less-qualified individuals, as there are few well-skilled individuals in the QS field. In Sri Lanka, there is less number of professional QSs who retain in public sector organisations (ICRAMCS, 2011). Although government sector is the main partner of the construction industry, they are not effective as much as required. Hence, most of professionals have not enough responsibilities according to their qualifications. Therefore, the professionals do not retain in public sector organisations.

2.3. HUMAN RESOURCE MANAGEMENT

Human resource management (HRM) is the sense of getting things done by people (Institute of Personal Management [IPM], 2010). Although the history of HRM is very short, the present status of the field of HRM has been achieved after years of evolutionary development. It is an essential part of every manager's responsibilities, yet many organisations find it advantageous to establish a specialist division to provide an expert service dedicated to ensure that the human resource function is performed efficiently. Construction organisations which are functioning in Sri Lanka expect experienced managers in order to manage their

HRM activities and functions efficiently and effectively (Arulrajah and Opatha, 2012). Kodippiliarachchi (1997) argued that HRM should be given the highest priority as it is a major resource input to the construction industry. There is a growing emphasis on effective HRM, as people should no longer be treated as a "cost", yet as a company's greatest "asset" and central source of competitive advantage (Druker and White, 1997). In order to retain these assets, it is necessary for employees to experience job satisfaction. This means that HRM must be given a more strategic role in organisations (Martell and Carroll, 1995). Normally, HR managers have the responsibility to recruit and retain the employees in any means by using every possible technique (Pomoni, 2009).

2.3.1. RECRUITMENT

Recruitment is one of the critical and important outcomes of Human Resource Planning (IPM, 2010; Clarke and Hermann, 2007). Stone and Raymond (1998) defined recruitment as the process of seeking and attracting a pool of people from which qualified candidates for job vacancies can be chosen. Ghosh (2000) argued that recruitment is the process of announcing job opportunities to the public in such a way that good number of proper employees will apply for organisation. Clarke and Hermann (2007) stated that strategies for recruitment and retention might be expected to vary according to the degree to which skill strategies exist or skill-sensitive nature of different labour markets. The construction industry is likely to have its own recruitment practice, due to the nature and structure of construction work and accordingly informal recruitment approaches have been the dominant approach (Lockyer and Scholarios, 2007). Moreover, effective recruitment methods are necessary to attract and to retain a quality workforce in an organization and this can be achieved if the recruitment process can be made more objective and formal (Ordanini and Silvestry, 2008; Lim and Ling, 2012).

2.3.2. RETENTION

Retention can be defined as a systematic effort by employers to create and foster an environment that encourages current employees to remain at the same employer having policies and practices in place that address their diverse needs (IPM, 2010). In order to retain the employees, the HR managers generally use techniques such as motivation, training and development, rewards and incentives and performance appraisal.

Motivation can be described as an inner generator of actions and reactions which optimises the human resource in the production process (Olomolaiye *et al*., 1998). According to IPM (2010), motivation is the act of stimulating someone or oneself to get a desired for a course of action and to push the right button to get the desired action done correctly.

Training is needed to meet the challenges inherent in twenty-first century work careers and organisations (Lim and Ling, 2012). Nowadays, employees are required to update continuously their skills and performance (Bucknail, 2012). Extensive orientation training throughout employees' careers also tends to improve their productivity (Ichniowski and Shaw, 1999). The main motive of having training and development is to increase a person's knowledge and skills (Hee, 2011). Many firms spend huge sums on training, believing that their employees' performance will improve after these trainings and thereby, increase the firm's productivity (Yamnill and McLean, 2001). Training is a systematic process of enhancing knowledge, skills, attitude and technology that is needed to assist a person to perform better in the present job (Colquitt *et al*., 2000). Development refers to helping an individual to meet up to the expectations and requirements of the demands of the job (Chen and Klimoski, 2007). Furthermore, Colquitt *et al.* (2000) stated that the development is most valuable aspect in employer's career.

Lim and Ling (2012) stated that reward system should be a package or system that consists of rewards and benefits such as holiday leaves, medical benefits, transport allowance and performance bonus. Further to authors, the main purpose of a reward system is to reward and retain good employees, motivate them to perform at their best and attract the right applicants to the job.

Performance appraisal is a system that is important to a number of important organisational decisions, especially, regarding incentives, rewards and promotion (Wiese and Buckley, 1998). Performance appraisal could be defined as a systematic evaluation process of a particular job performed by an individual during a particular period and giving value to its effectiveness whilst providing feedback to the job incumbent

(Erdogan, 2002). The main purposes of implementing performance appraisal system in an organisation are to ranking the employees, appraising the top performers, and enforcing others to perform well.

Currently in the construction industry, there are less organised staff management programs (Brandenburg *et al*., 2006). It may be directly affected to organisation performances (Hee, 2011). Lim and Ling (2012) said that construction firms mostly recruit employees through the firm's web site and through press advertisements due to the low cost. Although it is not popular so much, third parties such as job agencies, employee suppliers are used to recruit professionals in public sector construction organisations (Wright and Davis, 2003). Furthermore public sector organisations use internal recruitment as much as possible due to the less cost and less time consumption. In order retain the employees, organisations mostly uses promotions, trainings and employee motivation schemes. Training and development and incentives are most often HR functions which are used to improving staff retention (Navarathne *et al*., 2008). In some organisations, exit interviews will be undertaken when an employee informs his or her resignation, in order to find the reasons for their resignation yet this is done informally (Lim and Ling, 2012).

3. Research Method

Survey approach was selected as the most suitable research approach for this study since it was undertaken to explore the reasons for the shortage of QSs in public sector and steps to be taken to resolve the issue. Accordingly, data was collected through a questionnaire survey and a series of interviews. The questionnaire survey was carried out for a sample consisted of forty five QS professionals. Questionnaire data was analysed by using the RII method and Binomial Test. Subsequently, five semi structured interviews were carried out with Human Resource Managers and Personnel Managers in public sector construction organisations in order to identify their perspective regarding the research problem. Content analysis was used to analyse the data which are collected from interviews which includes data reduction, data display, and conclusion drawing. Eventually, conclusions were drawn and the recommendations were put forward based on the analysis.

Tables 1 and 2 show the details of respondents of both questionnaire survey and semi structured interviews.

Table 1: Details of the Respondents of Questionnaire Survey

Type	No. of Respondents	Percentage of Respondents
Client	9	26.5%
Consultant	16	47%
Contractor	9	26.5%

Table 2: Details of the Respondents of Semi Structured Interviews

Respondent	Designation
Interviewee A	Deputy General Manager (HR)
Interviewee B	Personal Manager
Interviewee C	Deputy General Manager (HR)
Interviewee D	Deputy General Manager (HR)
Interviewee E	Personal Manager

4. Data Analysis and Research Findings

4.1. Analysis of Data Collected from Questionnaire Survey

Thirty four questionnaires were completed and collected from forty five distributed questionnaires (75.55%). The respondents were selected in such manner that they represent Employers, Contractors and Consultants. This selection was done to obtain that views and perceptions of respondents who are involved in different types of organisations. Table 3 shows the eligibility of the selected respondents to answer the questionnaire survey.

Table 3: Experience of Respondents

No. of Years	Total Experience		Public Sector Experience	
	No. of Respondents	Percentage	No. of Respondents	Percentage
0-5	12	35%	25	73.5%
5-10	8	23.5%	5	14.7%
10-15	6	18%	1	3%
More than 15 years	8	23.5%	3	8.8%

According to the Table 3, more than two third of QSs have less than 5 year experience in public sector construction organisations and majority of respondents have less than 5 year experience in construction industry. There are only four QSs out of thirty four have more than ten year experience in public sector construction organisation. This indicates the unwillingness of the QSs to retain on the public sector. Moreover, the findings will confirm the general statement which rooted in the Sri Lankan construction industry that public sector is suitable either for a beginner or for a person who close to his or her retirement. The reason for this statement is that as fresh QS, what the employee value is the experience from a reputed organisation which assists his or her future career rather than the salary. On the other hand, a person who close to the retirement value the retirement fund as a stable living for his or her life. These two reasons clearly define that public sector provides low salaries. Therefore, in between QSs who are neither a fresher nor a person who close to the retirement prefer the private sector due to low salary schemes.

Any construction project is carried out according to the Royal Institute of British Architects (RIBA) plan of work. Therefore, the study required to identify whether the public sector QSs follow the RIBA plan of work in order to gain an idea about the opportunities they get to perform as public sector professionals, level of performance and their current standard as QSs. Table 4 indicates the probability of using the stages in RIBA plan of work in the current public sector in Sri Lanka.

Table 4: Results of Traditional Role

Stage	Yes	Cum. Probability	Result
Feasibility Study	11	0.987846745	Not Biased
Outline Proposals	31	3.83006×10^{-06}	Biased
Preliminary Design	29	1.92791×10^{-05}	Biased
Detailed Design	23	0.028806336	Biased
Final Design	25	0.004520593	Biased
Tender Period	20	0.195764153	Not Biased
Tender Evaluation	20	0.195764153	Not Biased
Award of Contract	20	0.195764153	Not Biased
Construction	17	0.56791688	Not Biased
Completion of project	12	0.971193664	Not Biased

The analysis was done by using binomial test. The purpose of using binomial test is to check whether the results are up to the appropriate standard or not. Probability which less than 0.05 are considered as biased to the answer “Yes”. Rest is neglected due to the less consideration.

According to Table 4, only four stages of RIBA plan of work are frequently implemented in public sector QSs and rest is disregarded. This result shows that there is very less scope of work done by the QSs in public sector organisations due to less delegation of authority. Since the QSs do not get opportunities and challenges which enhance and uphold their career, their willingness to work, creativity, logical thinking, decision making skills and interpersonal skills will be diminished. The ultimate unfortunate result will be employee turnover from the public sector construction organisations. This scenario is further confirmed by the details shown in Table 3. Table 5 is consisted of the results of the binomial test which conducted to observe whether there are any innovative modern QS related duties are performed in the public sector and whether the opportunity of handling those duties are given to the professional QSs.

Table 5: Results of Modern Role

Evolved Role	No. of Yes	Cum. Probability	Result
Value Management	14	0.885259493	Not Biased
Risk Management	4	0.999999617	Not Biased
Contract Management	17	0.56791688	Not Biased
Dispute Resolution	12	0.971193664	Not Biased
Facilities Management	1	1	Not Biased
Construction IT Management	7	0.999902437	Not Biased

According to Table 5, all modern duties of QSs are not biased to the answer "Yes". It reveals that the practices of modern functions by the QSs in public sector construction organisation are very less. This is also affected to the shortage of QSs in public sector organisations. The professionals generally walk away from the public sector finding places that they can expand their skills and knowledge due to the natural urge they feel to find challenges. However, it is confirmed that they have less opportunities in public sector organisations. Majority of QSs in publics sector do not obtain full satisfaction by working in the public sector construction organisations. Only five respondents mentioned that they are satisfied of working public sector and it 15% of the total respondents. Table 6 consists of the main reasons that the QSs are reluctant to retain in the public sector.

Table 6: Obstacles for QSs in Public Sector Organisations

Obstacles	RII	Rank
Low salary scheme	76.88%	1
Less opportunity to involve with new directions of the profession	75.63%	2
Less opportunity of promotions	73.75%	3
Less opportunity of dealing with various problems	70.63%	4
Less amount of work under scope	68.75%	5
Less motivation	66.25%	6
Ineffectiveness of recruitment process	61.88%	7
Problems of organisational hierarchy	50.63%	8

According to the survey results, the biggest obstacle for job satisfaction is low salary scheme in the public sector. Less opportunity for career development and promotions were also ranked in top positions. It is obvious that in the public sector, the salaries will be normally low when compared to private sector since Sir Lanka is a developing country however, when specifically consider about the wage difference of QSs in both sectors, it is extremely high. Thus, it is the main reason for the public sector QSs to walk away from the public sector construction organisations.

Majority of QSs in public sector hope to leave from the organisations and this situation will affect the organisation when performing QS functions. According to the literature synthesis, shortage of QSs has become a threat for the public sector organisations when they compete with private sector organisations. However, it should be understood that public sector has its own plus points such as reputation, stable income, preferred leave procedures and healthy retirement fund. Therefore, a positive change in the public sector by minimising the root causes of employee turnover will definitely retain more QSs in public sector. Majority of respondents agreed with the fact that proper human resource planning can mitigate the shortage of QSs in public sector. Table 7 consists of HR functions which are currently performing in the public sector construction organisations.

Table 7: Results of Current HR Practices

HR Functions	Yes	Cum. Probability	Result
Recruitment	30	3.08244×10^{-06}	Biased
Motivation	6	0.999980721	Not Biased
Reward and Incentives	20	0.195764153	Not Biased
Performance Appraisal	8	0.999589302	Not Biased
Training and Development	24	0.012153255	Biased
Employee Welfare and Grievance Handling	5	0.999996918	Not Biased

According to the Table 7, only recruitment and training and development functions are biased to "Yes". It means only those two HR functions are implemented in majority of public sector organisations. However, it can be clearly seen that these two functions are insufficient to retain the QSs inside the organisation. Therefore, other means to retain the QSs should be identified with regard to HRM. Rewards and incentive are given in some considerable percentage. However, according to the table 7, motivation, performance appraisal and employee welfare functions are rarely implemented in public sector construction organisations. Therefore, the majority of professionals including QSs are reluctant to work in the public sector. This situation should be eliminated through proper human resource planning in public sector. Table 8 consists of the HR functions identified by the respondents to mitigate the unfortunate situation of the public sector construction organisations currently face.

Table 8: Effectiveness of HR Functions for Job Satisfaction

HR Function	RII	Rank
Training and Development	78.24%	1
Reward and Incentives	75.29%	2
Motivation	74.12%	3
Recruitment	70.59%	4
Performance Appraisal	68.24%	5

According to the survey results of table 8, training and development has the highest RII value and it revealed that it is the most effective HR function for job satisfaction. Reward and incentives and motivation also received higher ranks. Performance appraisal is the least effective factor as per the respondents yet it carries a higher RII value of 68.24%. According to the Table 6, all the HR functions are effective and there is no function that can be disregarded due to ineffectiveness. Therefore, it can be concluded that the majority of QSs in public sector accepts that the effective HR management practices can assist to mitigate the shortage of QSs in public sector organisations.

4.2. ANALYSIS OF DATA COLLECTED FROM INTERVIEWS

Five semi structured interviews were conducted in order to find the current HR practices in public sector construction organisation for retaining more professionals and identify the future plans for recruitment and retention of QSs. Interviewees who contributed in this research were Human Resource Managers and Personnel Managers in public sector construction organisations.

According to the views of all respondents, HR practices are essential for the better performance of construction industry. Further to respondents, managing human resource is one of the most critical challenges often faced by the human resource managers. According to the opinions of five interviewees, it is clear that majority of construction organisations implement HR policies to retain more professionals. Among the HR functions mentioned by respondents, motivation, training and development are frequently used by the public sector construction organisations. Figure 1 consisted of the HR functions which are currently performing in the public sector and their popularity.

Name	Sources	References
Main HR functions to retain QSs	5	5
Motivation	4	4
Training & Development	4	4
Incentives & Promotions	3	3
Performance Appraisal	3	3

Figure 1: Coding Structure of HR Functions in Construction Industry

All the interviewees stated that establishing a separate division for recruitment and retention is valuable for construction organisation. They clarify their view by mentioning that the involvement of human resource for construction industry is relatively higher than other industries. They declared that due to the complexity of HR functions, it is important to establish a separate division and it will enhance the productivity of each HR function. As an initial step to the discussion every respondent gave a brief introduction of HR department of particular organization which includes their structure, roles and responsibilities, governing rules and other general information. According to their descriptions, every organisation has separate HR department under the supervision of a Deputy General Manager (DGM) and sub sections are supervised by HR Executives. Respondent A described about the circulars which are currently used in the division. Respondent C stated that the legal section of the organisation is also governed under the HR department. There is no fixed amount of QSs that should be taken per year in any organisation. In all organisations, recruitment process is implemented according to the existing vacancies. There is no such a fixed recruitment plan in any organisation.

Majority of public sector construction organisations are suffering from the shortage of QSs. This shortage will barricade their high standard performance failing to compete with the private sector skilled professionals. In order to mitigate the shortage, it is useful to investigate the reasons for this shortage. Figure 2 consists of the reasons for the shortage in public sector with regard to the opinions of HR managers who are responsible for attracting suitable gangs of professionals for the organisation.

Name	Sources	References
Reasons for shortage of QSs in public secto	5	5
Low salary	5	5
Less opportunity to career development	4	4
Less work under scope	3	3
Weaknesses in recruitment process	3	3
Less delegation of authority	1	1

Figure 2: Coding Structure of Reasons for Shortage of QSs

All the respondents primarily stated that the salary is the main reason for the shortage of QSs in their organisations. Although the critical reason is salary, there are number of tributary reasons for this situation. Respondent A described, "*the other thing is this is not a totally construction organisation. We act as a social services supplier. Because of that the QSs in our corporation have to do some informal activities which are not includes to their scope like social welfare*". It reveals that there is less work under the scope of QSs. As a result, the QSs are reluctant to work in public sector organizations. Respondent D had a similar opinion on this reason. He said, "*QSs in our corporation have to do some informal activities which are not included in their scope; for example social welfare*". According to the respondents, all the public sector construction organisations are governed by the circulars passed by the government of Sri Lanka. Therefore, an organisation cannot act individually, and recruit professionals. Hence, they have to face such shortages. Respondent A stated that she required some changes in Management Services Circular No. 30 of 2007 from the Ministry of Finance to recruit more professionals. All the decisions should be approved by the board of directors as well as by the Minister and the Cabinet. According to the respondents, although there is a shortage of professionals, they have to implement the HR practices within the limitations and also there are some delays in approving the decisions from the Parliament.

Retention is a systematic effort to create the job satisfaction of the employees to remain at the same working place. The research problem is also based on the issue that reluctance of QSs to retain public sector. All the HR personals whom interviewed stated that they have implemented the retention procedures up to some extent. Further to respondents, they have implemented some programmes and schedules to retain the professionals including QSs under the limitations of government rules and regulations. As most of QSs resigning from public sector due to the low salary, at this moment public sector organisations have implemented providing some allowances. Respondent A stated that graduate QSs are given the trade allowance of Rs.10000/= per month as financial motivation.

According to the respondents, they had offered the chance for the QSs to attend in training programmes both locally and internationally. According to the literature training and development is very effective to retain construction professionals (Yankov and Kleinar, 2001). Furthermore, the employee welfare is also concerned by the organisations and according to the respondents; they have some financial allocations from their annual budget for the employee welfare. Accordingly, it is clear that HR divisions are currently working on retaining the QSs in their organisations yet require improvements to achieve full retention. Figure 3 shows the future strategies which will be expected to implement by public sector construction organisations in order to retain more QSs.

Name	Sources	References
Future strategies to retain more QSs in public sector	5	5

Name	Sources	References
Salary Increment	4	4
More opportunities for training and development	4	4
Performance Appraisal	2	2
Expansion of Duties and responsibilities of QSs	1	1
Employee Welfare	1	1

Figure 3: Coding Structure of Future Strategies to Retain More QSs

All respondents paid their attention towards the expansion of opportunities for training and career development programmes as well as continuous learning facilities. Respondent A stated that "*we hope to give more opportunities for the professionals for their career development. Under this we try to get chances for foreign scholarships as well as training programmes".* Respondent E also pointed out that facilitating for higher studies of professionals will assist to retain them in public sector. Furthermore, respondent B stated that they are willing to expand their employee welfare programmes within the organisation. He further mentioned about bank loans, insurance, medical coverage, educational assistance for children and other welfare facilities which will be supplied in the future as a mean of employee retention. The respondents stated that they are willing to implement new plans and strategies in order to retain more QSs within their organisations as well as enhance the productivity of them. According to the respondents, some changes and revisions of current HR policies will be a catalyst to retain more professionals. Although the HR managers prefer to increase the amount of QSs, they have to work under the rules and regulation of the government so that it will not be an easy task to achieve.

As a summary of whole interview analysis, there is a shortage of QSs in public sector construction organisations. This situation has been arisen due to various issues. Due to this situation, they have to face number of challenges in construction industry to survive. According to the HR experts in public sector, they have implemented some plans to overcome this problem but it seems they are insufficient. Therefore, the necessity of proper framework to recruit and retain QSs is urgent for public sector organisations. After the analysis of data collected from questionnaires and interviews, the framework was developed. The reasons for the shortage of QSs in public sector were identified and proposals for mitigate the issue were discussed in the analysis. The framework consists of the issue and perspectives of two parties who are relating to the issue. Furthermore, it describes the actions to be taken to mitigate the problem and the barriers to implement those plans. According to the framework, the HR managers should concentrate mostly on the salary increments, training and development and offering promotions. The public sector QSs are reluctant to retain in public sector due to low salary, less opportunity for career development and conflicts regarding the delegated authority among them. Due to the shortage of QSs in public sector, they have faced some critical challenges as the main individual partner of the construction industry. Hence, they seek for a solution of this issue. The HR managers have realised that there should be changes and improvements in current practices. According to their viewpoints, even though they are willing to change the current situation, they cannot exceed the limitations of the government. The framework to recruit and retain professionals QSs in Public Sector is demonstrated in Figure 4.

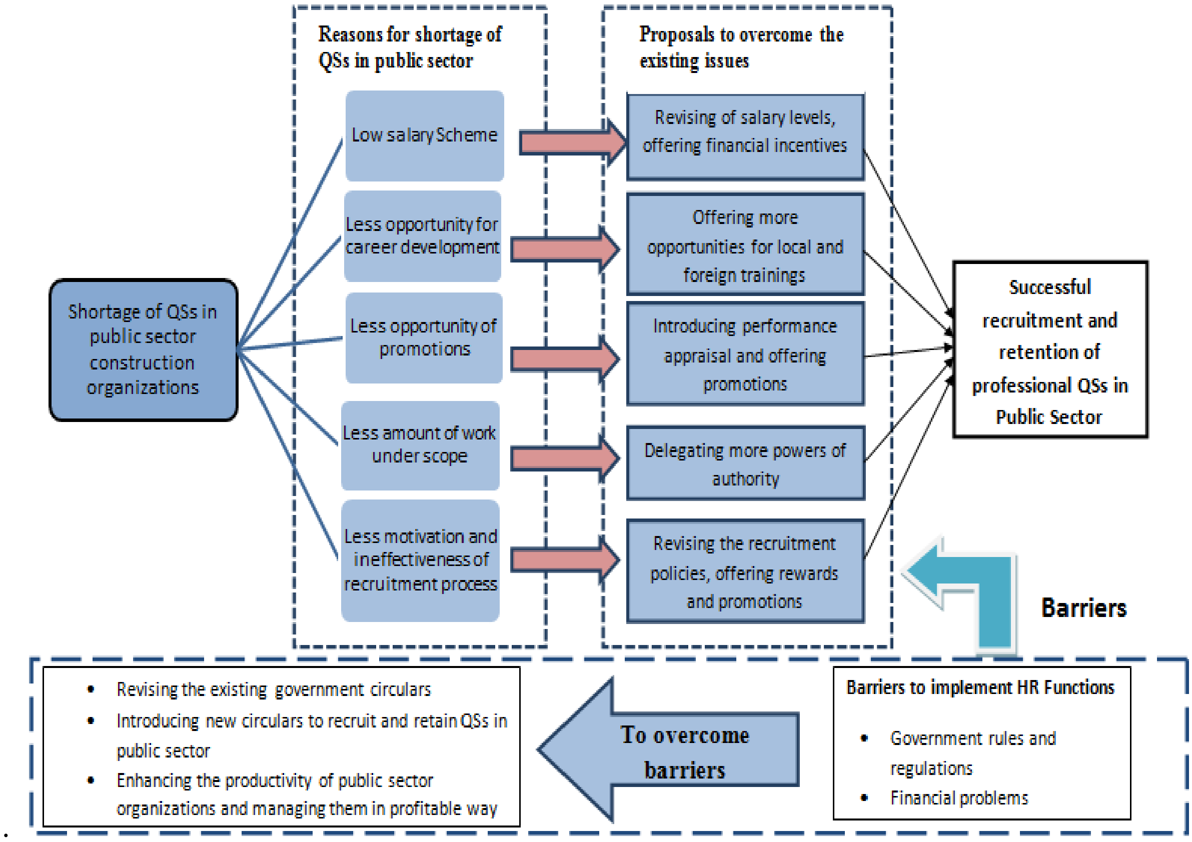

Figure 4: Framework to Recruit and Retain Professionals Quantity Surveyors in Public Sector

Furthermore, it is revealed that implementing new HR functions will be an additional cost for the organisation. As majority of public sector construction organisations are not profit earned ones, they do not have enough financial resources to implement additional HR functions. In addition, they have to request from the ministries to allocate additional funds to recruit and retain more QSs to public sector. As shown in Figure 4, the final solution for the problem is to revise or change the existing circulars and regulations in such a way that the change will positively assist the retention of QSs in public sector. They should be revised to stabilise the profession of Quantity Surveying in public sector as well as to increase the salary levels, career development opportunities, higher education opportunities and other welfare facilities. Furthermore, the allocation of additional financial resource is another solution for the issue.

5. DISCUSSION

Research findings clearly revealed that there is a shortage in public sector QS professionals. It further indicated that the QSs obtain very narrow scope of duties as well as the chances to expand their knowledge in public sector is very less compared to private sector. These facts are in line with the findings of Moodley (2012) since the author revealed that there are few well-skilled individuals in QS field in public sector. Similarly, ASAQS (2012) stated that innovation and best practices in the private sector create more job opportunities for QSs than in public sector. According to the survey results, employee job satisfaction is very low in the public sector. Low salary schemes, less opportunity to involve with new trends of the profession and many other reasons were identified as the root causes for the dissatisfaction of QSs in public sector. Similarly, Sugeewan (2009) stated that more than 70% of graduate QSs had gone abroad for higher salaries and rests were willing to employ in private sector. Moreover, ICRAMCS (2011) stated that less amount of professionals in public sector are willing to retain and this situation has become a threat to the public sector construction organisations. In addition, the findings revealed that more than 80% of the QSs are willing to resign from the public sector.

As per the research findings, more than 90% of professionals think that implementing proper HR practices in public sector will mitigate the shortage of QSs. However, only recruitment and training and development functions are currently implemented in the public sector. Motivation, incentives, rewards, promotions, welfare facilities are not used frequently. Especially, performance appraisal is completely ignored. As mentioned by Kodippiliarachchi (1997), HRM should be given a prior consideration since it is a major resource input to the construction industry. Furthermore, Druker and White (1997) stated that people should no longer be treated as a "cost" but as an "asset". According to the views of respondents, training and development was ranked as the most effective HR function for job satisfaction. As professionals, they are willing to expand their knowledge. This is in line with the findings of Lim and Ling (2012) since they have emphasised the importance of meeting the challenges inherent in twenty-first century by continuously upgrading and uplifting the career life. Further to authors, the main motive of training and development is to increase a person's skills and performance.

According to the research findings, HRM is essential in construction industry due to the multi-disciplinary involvement and the requirement of high quality. Similarly, Navarathne *et al.* (2012) revealed that the quality of output is totally depended on the job satisfaction of the employees. Furthermore, Arulrajah and Opatha (2012) stated that HR functions are acting as a leading factor of the productivity of any industry. Research findings revealed that HR departments already identified the causes of employee shortage yet they have to implement the plans to avoid the shortage by adhering to the government restrictions. However, the public sector HR managers recognised the strategies to avoid the issue such as conducting training programmes, providing scholarships, allowances and welfare schemes within the boundaries.

The research findings indicate the importance of retaining public sector QSs. In addition, the findings put forward an effective framework to mitigate the employee turnover and attract, recruit and retain the QS professionals. Mitigating employee turnover will enhance the performance of public sector construction organisations by enabling to follow a sustainable construction practice. This is in line with the findings of Hee (2011) as it emphasised the importance of preventing employee turnover by enhancing and uphold the QS profession with proper skills and talents. When consider deeply about employee job satisfaction, it can be understood that well satisfied employees lead to sustainable construction practice. Sustainability can be described as preserving the human resource (professionals) for future generation while effectively taking their service at present. In addition, it is important to increase their willingness to work by mitigating frustration. The basic source of frustration will be unwillingness to work deriving from low salaries, less opportunities and less motivation. Therefore, by following the framework introduced by the study, the public sector can achieve sustainable construction practice.

6. CONCLUSIONS

Sri Lankan construction industry has shown an upward trend since 2009, after the ethnic war in some parts of the country. Although there is a rapid development in construction industry, there are some key problems in industry which may be affected to the output. Shortage of the professional staff including QSs is one of the major issues and the public sector is the most affected sector from the very issue. According to the survey results, public sector construction organisations prefer the services of professional QSs yet there is some reluctance of QSs to retain in public sector. Due to this situation, a shortage of QSs has been created in public sector and it has created a big impact to the organisations. The study indicated that more than 80% of QSs in public sector do not obtain the satisfaction of working in the public sector organisations. The reasons are low salary, less opportunity for career development and less delegated works and responsibilities for the profession. Majority of QSs intend to resign from the current public sector organisation and work in the private sector. This situation has created the gap between demand and supply of the QSs in public sector construction organisations.

HR practices are highly impacted on the effectiveness and efficiency of any industry. As mentioned in literature, construction industry is one of the industries which use large gang of human beings including professional staff, labourers, suppliers and manufacturers. Furthermore, HRM should be given the highest priority as it is a major resource input to the construction industry. According to the results of survey, majority of QSs stated that the existing shortage of QSs in public sector can be eliminated by using proper

HR practices. Moreover, they pointed out main HR functions such as motivation, training and development, employee welfare and rewards and incentives which should be implemented to retain more QSs. Being one of the key professional experts in the construction sector, QSs have the utmost responsibility to address the key cost, financial and contractual issues of the construction process. The main responsibility of QSs is to control the public money and monitoring the way it was spent. Due to the shortage of QSs in public sector, they have to face various challenges. Mostly they have to use private sector consultants for a higher price and some private contractors have earn unfairly from public sector projects as there are no QSs to control the situation. Furthermore, disputes are regularly arising due to the less advice on cost related issues. Due to this unfortunate situation, public sector had to face financial crisis.

It was revealed that only few HR practices have been implemented in public sector and this situation has created the dissatisfaction of QSs of their job. Moreover, it was recognised that HR functions will assisting in mitigating the shortage of QSs in public sector. The HR managers in public sector organisations have implemented programmes to attract and retain QSs in their organisations yet they are not sufficient to fully manage the situation. As a solution, HR divisions have now discussed with the government to revise the government circulars in order to attract more QSs as well as they have planned to offer more programmes which assist the career development. The HR managers often have to implement HR functions within the boundaries declared through circulars of the government. Although they have identified some weak points in these circulars, they are restricted to take actions until those circulars are revised by the Parliament. Furthermore, revising those circulars will take more time so that, there is a shortage of QSs in public sector construction organisation. However, the study introduced a framework which is ideal to attract, recruit and retain the QSs in government sector by pointing out the root causes of shortage of professional QSs, strategies to prevent the causes, barriers for implementing the strategies and methods to overcome those barriers. The study firmly recommends providing a vital importance to employee satisfaction in public sector and using the introduced framework to retain the QSs in public sector. Further, the study recommends the HR divisions to pay more attention regarding employee turnover and take actions against it following the government rules and regulations. If the employee turnover will eliminated from the public sector, it can be identified as a sustainable construction practice since they preserve human resource for future use by utilising it currently in a proper manner.

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SUSTAINABILITY CONCERNING TO PUBLIC PROCUREMENT PROCESS IN CONSTRUCTION: LITERATURE REVIEW

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ABSTRACT

In the year 1977, economy of Sri Lanka liberalised and opened up to foreign market with investment to deregulate domestic construction industry. Further, the economy has shown transition features since 2009, after end of 30 years' war. Public Procurement Process (PPP) mainly considers satisfaction of the stakeholders in line with development objectives of the country. Hence the PPP is the integral part of economic development of the country. However, the economic development of Sri Lanka has shown lagging features when compared to economic history of other developed countries due to the reasons that the existing PPP has not given fullest uplift in line with current global requirement.

Thus, the practitioners in the industry should find the way to enhance and upgrade the existing PPP to link with available challenges. Literature revealed that developed countries have utilised numbers of benefits by implementing Sustainable Public Procurement Process (SPPP). Accordingly, incorporate the sustainability concerns than the time, cost, and quality aspect to the existing PPP is one of the best practicable and cost effective possible alternative solutions to bridge the gap. Thus, this paper focused on detailed analysis on sustainable concerning to PPP with in Sri Lankan context base on secondary data.

Hence, relevant areas scrutinised through the comprehensive literature review to achieve the objectives of the study. Further, experts in the field of procurement also consulted to gather the opinions and views in order to evaluate the feasibility of desired outcomes.

Keywords: *Construction Industry; Procurement; Public Procurement; Sustainable Public Procurement.*

1. INTRODUCTION

The procurement process was used effectively in many industries as the key part when acquire goods, works and services by given equal weightage to the aspects of time, cost and quality in order to achieve desired objectives of the organisation. Presently, the procurement process plays a major role not only in the organisation but also in the country to achieve their mission and vision (Wales, 2010; Walker and Brammer 2009; National Procurement Agency, 2006).

The activities of the procurement identified as continues processes from risk assessment, selection of source, evaluation of alternative solutions, contract award, payment, and management of a contract up to the end of defect liability period (Manu, 2005; National Procurement Agency, 2006). The procurement process in construction industry was identified as very sensitive to change in line with the requirement of external environment of economic, political, financial, legal and technological. Thus, the construction industries in the world are striving to tackle these changes through the new and innovative ways of construction, efficient resource utilisation and better organisation of the activities of the projects (Rameezdeen and Silva, 2002). Accordingly, contemporary version of the existing procurement process that link with requirement of external environment as per the global needs has identified as sustainable procurement. Sustainable Procurement Process (SPP) documented as broader and long term concept. Besides the sustainable procurement has direct link with the sustainable development of the country. Hence SPP concluded as an integral part in order to achieve the present global needs and uplift the economy of the country and living standards of the stakeholders (Kim and Shunk, 2004; World Bank, 2010; Hawkins *et al*., 2011; Srivastava, 2007; Preuss, 2009; Walker and Brammer 2009; Nijaki and Worrel, 2012; Williams *et al*.,2007).

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The aim of the paper is to discuss the applicability of SPPP as a best practice to overcome the existing challenges of the PPP in the construction industry. The scope covers introduction, significant, and challenges of the PPP. Accordingly focuses on critical literature identified the SPPP as best remedial measure to the challenges and bridge the gap in line with the global needs of the stakeholders, further, forwards to discussions with future research agenda. The paper mainly based on the secondary data.

2. PUBLIC PROCUREMENT PROCESS (PPP) IN CONSTRUCTION INDUSTRY AND ITS SIGNIFICANCE

The categorisation of the procurement process mainly depends on the way of implementation of ethics and strategies of the process. Hawkins *et al*. (2011) divided the procurement process into two groups; procurement for profit and not for profit. Furthermore, identified that procurement process for profit behaves towards opportunistically and conversely, moreover, argued that not for profit behave towards more opportunistically while not considering opportunities of subordinators' behaviours. However, the procurement process on not for profit has room for development of the process. Finally, noted that not for profit ethics and strategies are used in public procurement (Manu, 2005). National Procurement Agency (2006) mentioned that public procurement is used by Procuring Entities (PE) to obtain goods, services or works by the most appropriate manner. It would include purchase, rental, lease or hire purchase, including services incidental to the provision of the said goods or services or the execution of the works. Moreover, the World Bank (2010) described that public procurement is the process use by the government to buy the inputs for vital public sector investments. Those investments both in physical infrastructure and strengthen institutional and human capacities lay foundations for national development.

Accordingly public enterprises enter in to many business relationships, both upstream and downstream. However, the objectives of the public sector are wider than the procurement process of the private sector (Murray, 2009; Larson, 2009). Such objectives include the effective delivery of a wide range of public services, including law and order, health, social services, education, defence, transport, and the environment. Hence, the scope of the procurement in public sector is much wider than the scope of the private organisations in terms of the diversity and needs of customers being served (Erridge, 2007). Since, 2005 the strategic role of public procurement has emerged, further it has extended the basic cost saving function to cover the broader government objectives. Further the public procurement is subject to special rules in order to secure that goods and services are acquired at competitive prices (Zheng *et al*., 2010).

Further, Masterman (1992), Frank (1998) and many other authors in procurement attempted to categorise the PPP in construction industry under several procurement systems. Rameezdeen and Silva (2002) categorised the PPP into four broader systems; 01) Traditional Procurement System (Measure and Pay, Lump Sum, and Prime Cost), 02) Integrated Procurement System (Design and Build/ Construction (Build Own Operate, Build Operate Transfer, Build Own Operate and Transfer) and Turnkey, etc.), 03) Management Oriented System (Construction Management and Project Management, etc.), and 04) Collaborative System (Joint Venture, Partnering, etc.).

Moreover, the construction industry has recognised as an economic regulator and plays a key role in its economy providing significant contribution to the national output (Turin, 1973; Hillebrandt, 1984; Ofori, 1990). Thus, PPP in construction industry is identified as paramount importance for economic development and long term growth of the country. Within the overall pattern of public expenditure in construction industry, the portion of public expenditure attributable to purchases of goods and services that has been the subject of significant attention of the stakeholders (Fernandez, 1996; Trionfetti, 2000; McCrudden, 2004; Brulhart and Trionfetti, 2004). Further considering with total public expenditure, this interest arises in part from the absolute scale of public procurement between 8% and 25% of the Gross Domestic Products (GDP) of developing countries and 30% purchases of goods or services developed countries (OECD, 2000; European Commission, 2006; Afonso *et al*., 2005). Furthermore, public procurement process in construction industry is also a significant activity in the developing world (Evenett and Hoekman, 2005).

3. SIGNIFICANCE OF "PPP" IN SRI LANKAN CONSTRUCTION INDUSTRY

In the year 1977, the reigning political party took major steps to liberalise the economy in Sri Lanka. This involved several inter related initiatives to open up the economy to foreign trade and investment to deregulate domestic business in order to reduce the role of the state in economic affairs. At present, the economy of the Sri Lanka has been shown transition features since end of the war in 2009. Therefore, the procurement systems are also in transition era (Central Bank Report, 2010; Central Bank Report, 2011). Further statistical figures of the Central Bank Report (2012) revealed that government of Sri Lanka spent on infrastructure development Rupees billion 310.3, 335 and 375.2 in the year of 2009, 2010 and 2011 respectively. Therefore public procurement process in construction industry of the country is identified as integral part in order to achieve desired aim of to be an economic hub in the Asian region. Hence, enhancement and improvement of the activities of public procurement process in construction industry directly benefitted to the nation in order to achieve the desired outcome (World Bank, 2010; Murray, 2009; Larson, 2009; Erridge, 2007; Zheng *et al*., 2010).

Central Bank Report (2012) found that the public procurement process in construction sector was the main driver of economic growth in Sri Lanka and mentioned that it makes the most significant contribution, reflecting the massive public investment programmes and several private sector projects. Further, noted that interest of the stakeholders has growth to moderate the existing process. Moreover, PPP is concerned with establishing and documenting what is required; soliciting the offers to provide supplies or services to construct or maintain infrastructure or to undertake disposals; awarding contracts to successful tenderers; monitoring that which was contracted to be provided is indeed provided; and paying contractors for executing their contracts until end of defect liability period (Raymond, 2008; National Procurement Agency, 2006). Further, Rameezdeen and Silva (2002) mentioned that majority of the government projects in Sri Lankan construction sector carry out under the traditional procurement system of Measurer and Pay in order to ensure the transparency and accountability as per the rules and regulation specified in procurement guidelines and financial regulations when compared with other procurement systems.

However, the government investment for major projects irrespective of the procurement systems in the field of infrastructure has directly contributed to economic growth in Sri Lanka. Following the liberalization of the economy in 1977, investment was raised from 14.4% of GDP in 1977 to 33.8% in 1980, with an average of 27.6% during 1978–84 and in 2010 to 2012 the average of 30%. This was due to the ambitious public procurement process accompanying reform after the 30 years of war (Central Bank of Sri Lanka, 2012; World Bank, 2010, 2012; Murray, 2009; Zheng *et al*., 2010; Larson, 2009). Hence, this improvement has direct positive affect to the construction industry. Accordingly, in line with the medium term development plan of the country, the vision of the Sri Lanka was established to become a global hub between the East and the West and become upper middle income country by 2016 (The Wold Bank, 2012).

Therefore, PPP in construction industry has direct link with the investments and economic development of the country. Hence, effective and efficient improvement of activities of PPP positively affected to uplift the economy of the country (Central Bank Report, 2010; Central Bank Report, 2011). Elaborating in this regard Shiyamini *et al*. (2005) emphasised that government is major client and regulator in the construction procurement in Sri Lanka. Moreover, the PPP of construction industry is identified as one of the backbones of the economy of Sri Lanka (Latham, 1994; Egan, 1998). In order to facilitate to that the public procurement process play significant role to achieve the medium term development goals of the country. Hence, the procurement process of the construction industry should be substantial and will have to be met by both the public and private sectors to optimise alignment with the vision of the medium term development plan of the country in line with the global needs (Central Bank of Sri Lanka, 2011).

Thus the procurement process should upgrade to achieve the desired goals of the organisation or country by considering the requirement of stakeholders and global needs (Srivastava, 2007; Preuss, 2009; Walker and Brammer 2009).

4. CHALLENGES AND BARRIERS FOR THE "PPP" IN CONSTRUCTION INDUSTRY

The current activities of the public procurement process in Sri Lanka carryout in line with the rules and regulations specified in the financial regulations and procurement guidelines and manuals of the government of Sri Lanka and the funding agencies. The funding agencies of the World Bank (WB), the Asian Development Bank (ADB), and the Japan International Cooperation Agency (JICA) require that borrower should ensure that procurement system is sustainable and selection procedures should base on quality and life cycle based evaluations in order to overcome the deficiencies of the existing system. However misunderstanding and misidentification of the concept of the sustainable development by the stakeholders is the prevailing key dispute (Williams, 2007; World Bank, 2012). Further, misidentification of procurement law and negative attitude of the procurement officers are also identified as major challengers (Williams, 2007).

Raymond (2008) noted that Sri Lanka has no continuity in a national strategy on the procurement process unlike developed countries. Moreover, the author pointed out that the existing PPP in Sri Lanka not considers the global needs and requirements in line with the key principal of sustainable development. In addition lack of knowledge of the officers and fraud and corruption involvement also negatively affect to the activities of procurement process. Therefore, present PPP not compatible with the aspects of sustainable development of the country. As such, the government of Sri Lanka and the funding agencies have identified that the PPP in Sri Lanka should be upgraded to expedite the future economic development to become a one of fastest growing economy in the Asian region (World Bank, 2010; Biller and Nabi, 2013; Murray, 2009).

Though, cost has been found to be the leading barrier to improve the procurement process and lack of support by the top management as leading facilitator also identified as obstacles. There are notable differences could be seen from developed countries to Sri Lanka on uses forms of capital efficiently to sustain economic growth and development in the medium and long term. Hence, the main challenge remains to Sri Lanka is high initial cost involvement to upgrade the system in line with the global need toward better infrastructure facilities to increase economic growth in the area of construction, services and manufacturing sectors (Biller and Nabi, 2013).

Hence literature revealed that number of challenges and barriers of the PPP in construction industry as obstacles to provide the desired outcome of the stakeholders in Sri Lanka compatible with the global needs. Moreover it was identified that the interest to upgrade the PPP in construction industry has been increased by the stakeholders in line with the concept of sustainable development as per the global requirements. In the next chapter discusses remedial measures to the prevailing challengers through the comprehensive literature review.

5. Remedies for the Challenges and Barriers of "PPP" in Construction Industry

Administrative remedies identified with consideration and awareness of environmental protection and social laws to address the existing challengers of the PPP as mentioned in first paragraph of the previous chapter. The law concerning on sustainable development is addresses the treatment of hazardous waste, occupational safety, and the prevention of corruption. Further funding agencies identified that country should have a strong procurement regulatory framework in place, which ensures economy and efficiency, equal opportunities to compete, and a transparent procurement process. Furthermore encourage the development of domestic industries. Moreover, the legal framework has been developed by the funding agencies base on the United Nations Commission on International Trade Law (UNCITRAL) as based legislation to include institutional checks and balances in order to reduce the corruption and dispute (Williams, 2007; World Bank, 2012).

As stated in second paragraph of the previous chapter the remedies have identified for national strategy and development framework; the country embarking on sustainable development as national strategies should have positive reactions toward the norms of inclusiveness, equity and fairness. This strategy should also address environmental, social and economic challenges of the existing PPP. The European Commission identifies the most important driving forces behind the PPP as relevant policies and the increased awareness of environmental problems (European Commission, 2007). The author further mentioned that most member countries have developed national sustainable development strategies at developing stage to implement the targets agreed to arrive the national development. Moreover the experiences of current developed countries also provide further evidence that a strong continues national sustainable development framework is pivotal for address the existing challengers of PPP (World Bank, 2010; Biller and Nabi, 2013; Murray, 2009; Raymond, 2008).

Available resources and support of top management also identified as remedy for the challengers that identified in third paragraph of the previous chapter; the implementation of the PPP as desired by the stakeholders in line with global needs requires reforms in the areas of policies and investments in technology, research, education and information. Further adequate funding and institutional capacity also should be upgraded. The experiences of Sri Lanka have shown that existing budget was not sufficient to implement desired outcome. However on the other hand found that the country has established short terms targets to stream line the existing PPP. Accordingly the funding agencies have taken actions to analysis the existing PPP in Sri Lanka in order to upgrade and enhance the process in line with global needs. The action taken by both government and funding agencies positively affect to bridge the existing gaps of PPP in Sri Lanka (World Bank, 2010; Biller and Nabi, 2013; Murray, 2009).

Hence, majority of the literature found that sustainable development approach as best remedial measure to bridge the gap of the prevailing challenges of the PPP towards the development objectives of the country.

6. Sustainable Public Procurement Process (SPPP) and its Significance to Construction Industry

World Summit on Sustainable Development (2002) first time officially disclosed to the world the sustainable procurement as the process that promotes policies encouraging development and diffusion of environmentally sound goods and services. However the World Commission on Environment and Development's Report (1987) internationally recognised definition of sustainable as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The procurement actions in order to achieve desired outcome are same on the sustainable and existing procurement process (Interagency Procurement Working Group, 2006). Though, Steurer *et al*. (2007) and Mc Crudden (2004) argued that existing procurement process has drawn special attention on the aspects of cost, quality and time than social, environment and economic in order to achieve the value for money.

The concept of sustainable procurement introduce and promote in last few years, which can be explained in the following terms: "sustainable procurement (SP) is procurement that is consistent with the principles of sustainable development, such as ensuring a strong, healthy and just society, living within environmental limits, and promoting good governance" (Walker and Brammer, 2009 p. 21).

Steurer *et al*. (2007) emphasised that the SPP has been used by developed countries as best practice of current procurement process. Sustainable development encompasses environmental protection allied with the promotion of social welfare and economic growth. It is a principle aimed fulfils the needs of current generations by saving the required resources for future generations (D'Amico, 2010; Brauch M. D., 2012). Hence, sustainable procurement means taking sustainability considerations into account in the procurement actions. This means thinking carefully before buy, buying only what really need, purchasing products and services with high environmental performance and considering the social and economic impacts of a purchasing decision.

The SPP is about spending public funds on products, services, projects that foster sustainable development of the country. Currently, sustainability issues becoming vital in the developmental agenda of nations, it is time to shift the focus of public procurement systems from mainly immediate economic advantages to SPP systems which will result in long term benefits not just to governments but to all their constituents. Though a new concept, SPP is not another type of procurement; it rather seeks to address the environmental, social and economic consequences of procurement actions from design through manufacturing to use and final disposal at the end of defect liability period. The SPP is defined as a process whereby public institutions meet their needs for goods, services and works in a way that achieves value for money on a whole life basis in terms of generating benefits not only to the organisation, but also to society and the economy, whilst minimising damage to the environment. Finally the process upholds the principles of transparency, fairness (to both the supplier and society), long term economy, and accountability (Mueller (1997), Persson and Tabellini (2001), Shleifer and Vishny (1998), Strauch and Von Hagen (2000), Tanzi and Schuknecht (1997, 2000)).

The sustainable procurement is affected to potential saving of costs of the procured goods and services. Although it may lead to higher direct purchasing costs, the overall lifetime cost of a sustainable product less than the cost of other cheapest option. This is because the sustainable option can result in lower operating costs, maintenance and disposal costs. Thus, despite the higher initial purchasing costs, sustainable options can offer an important return on investment through reduced life cycle cost. Further, it results in an average decrease of overall costs for public organisations of around 1% (Pricewaterhouse Coopers, 2009). This percentage is based on lifecycle cost estimation for seven European countries (United Kingdom, Sweden, Finland, Denmark, Germany, Austria and the Netherlands). A reduction of 1% is significant in absolute terms, given the large value of public procurement. The cost reduction could be larger for nations with a higher percentage of procurement of the GDP in the developing countries. Further found that especially in the construction and transport sector major cost reductions can be achieved through sustainable procurement. The government require to staidly improve the investment in the field of infrastructure (The Wold Bank, 2012). Hence, application of sustainability concerns to the current public procurement process leverage the benefits for major regional and urban infrastructure projects in construction industry.

Williams *et al*., (2007) highlighted that the new trends in public procurement system and global need of upgrade the existing PPP in construction industry as the global population is increasing and consumption rates per capita are growing. Hence, human consumption of resources significantly exceeds what the earth can provide. Further, essential services such as clean air and water, a stable climate and viable forests and fisheries are in long term decline. The resources on which rely are being depleted at accelerating rates. Furthermore, stated that range of social, environmental and economic objectives can be delivered through the enhancement of the existing PPP.

Hence, effectiveness of the existing public procurement process in the construction industry in Sri Lanka should be upgrade by improving consideration of value for money, domestic and international confidence, and development of professionalism at all level, enhancing technology considering social and environment aspects (Raymond, 2008). Clement *et al*. (2007) emphasised that numbers of benefits have utilised by implementing sustainable procurement system than the existing procurement system to the construction industry. Elaborating in this regards further explained that benefits of implementing the SPP such as financial saving, achieve the goals of social, environment and health, drive local innovation, improve public image and increase legitimacy and contribution to the global sustainability. Accordingly, incorporate the sustainability concerns to the existing procurement process is the one of the best practicable and cost effective possible alternative solution to upgrade the existing procurement process. Moreover, Steurer *et al*., 2007 explained that the governments should take the full range of economic, social and environmental costs and benefits of public procurement into account for the sustainable improvement of the economy.

Based on the results of findings, suggested that there are several practical implications for the government policy makers in Sri Lanka. The policy makers should focus more on "buy from small and local suppliers" as well as retain an environmental focus and address future policy iterations. Further the government should provide sufficient financial support and should introduce sustainable procurement guidelines and awareness raising programs about sustainable procurement opportunities. Finally, the assistant should be obtained from the funding agencies and developed countries in continuing to develop and refine policy responses to the sustainable procurement challenges ahead.

7. "SPPP" TO BRIDGE THE GAP OF THE EXISTING "PPP" IN SRI LANKAN CONSTRUCTION INDUSTRY

As mentioned in previous chapter, interest to the sustainable procurement system has been increased by the stakeholders in Sri Lanka. Raymond (2008) noted that poor procurement practices hinder sustainable development and shown negative impact upon economic growth of the country. The Commonwealth Procurement Guidelines (2005) and Raymond (2008) highlighted that when procuring of goods, works and services all the relevant cost and benefits over the procurement lifecycle should be taken in to account. Furthermore Barrett (2000) and Korosec and Bartle (2003) argued that existing procurement process should be streamlined consideration of issues such as client satisfaction, public interest, social and environment impacts, fair play, honesty, justice and equity. Further, the authors emphasised that developing countries need to recognise the importance of the technique and benchmark to improve the public procurement process towards the sustainable aspects. Hence, sustainability concerns are identified as the best option to address the prevailing issues of the existing procurement process in Sri Lankan construction industry (Walker and Brammer, 2009; Rameezdeen, 2002).

Further, SPPP is identified as most accepted method to address the issues and deficiencies in existing PPP of the developing countries (Interagency Procurement Working Group, 2006). Moreover the construction industry is identified as an open system, hence, it is very sensitive to change with the needs and requirements of the stakeholders; further, its characterisation throughout the world is determined by the operating external environment, which consists of subsystems such as economic, political, financial, legal and technological. This has leaded the industry to be in a challenging state in addressing the changes forced by the subsystems in an efficient and effective manner. Thus, the construction industry in Sri Lanka is striving to tackle these changes through the new and innovative ways of construction, efficient resource utilisation and better organisation of projects. Consequently, PPP practiced in the construction industry has also been subjected to changes resulting in many newly innovated procurement systems that could be used to meet contemporary requirements in line with the current global needs (Turin, 1973; Hillebrandt, 1984; Ofori, 1990; Rameezdeen, 2002).

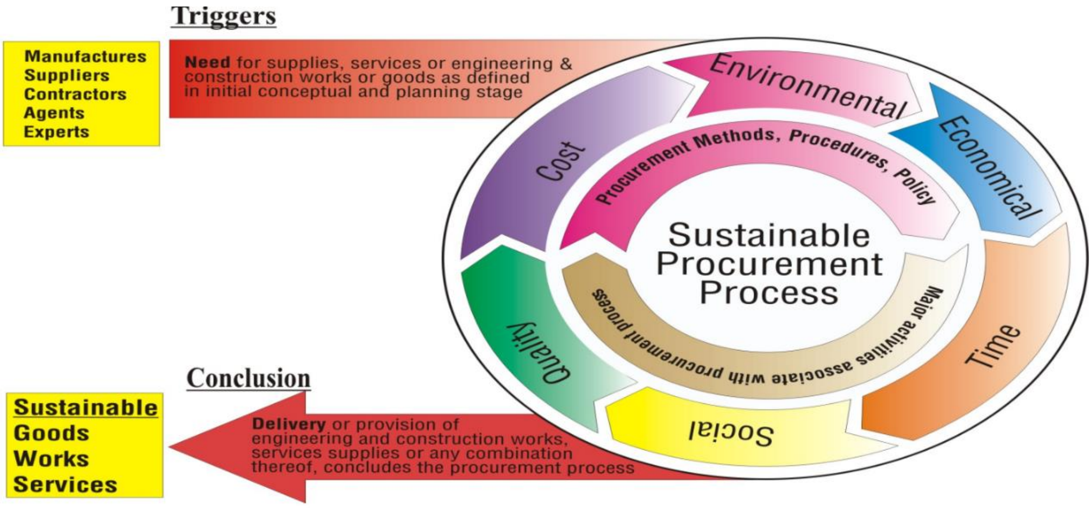

Figure 1: Sustainable Procurement Process to the Sri Lankan Construction Industry

Figure 1 illustrates procurement methods, procedures and polices link with major activities associate to the process in line with sustainable aspects. Further elaborate the triggers as input to the process and sustainable product as output. Therefore, existing PPP in construction industry in Sri Lanka should give equal weightage not only to the aspects of time, cost and quality but also to the aspects of social, environment and economical when produce the goods, works and services with consideration of value for money in line with the requirements of the stakeholders and the global needs (Interagency Procurement Working Group, 2006; Steurer *et al*. 2007; Mc Crudden 2004; Williams, 2007).

The main benefits from sustainable procurement can be summarised as: controlling costs by adopting a wider approach to whole life costs, achieving internal and external standards complying with environmental and social legislation, managing risk and reputation of the organisation creating new, vibrant markets ensuring security of sustainable supply for the future ensuring maximum community and financial benefits (Interagency Procurement Working Group, 2006).

The opinions of the experts in the field of procurement established the feasibility of the findings of literature and further mentioned that potential benefits of sustainable procurement include: long-term efficiency savings more efficient and effective use of natural resources reducing the harmful impact of pollution and waste reduction by promoting innovative products.

8. CONCLUSIONS AND THE WAY FORWARD

The aim of this paper was to identify the applicability of sustainability concerns to the PPP in Sri Lankan construction industry in order to bridge the gap of the existing PPP in line with requirement of the stakeholders and the global needs.

As mentioned previously, findings revealed that the PPP has number of challenges and barriers to improve the system. Further through the literature it was identified that SPPP as remedial measure to address the challenges and barriers of the existing PPP in Sri Lanka as per the previous experience of developed countries in line with the requirement of the stakeholders and the present global needs (The Commonwealth

Procurement Guidelines, 2005; Raymond, 2008; Walker and Brammer, 2009). Finally through the literature and the opinions of the experts in the field of procurement identified the gravity of consideration of the aspects of social, environment, and economical while carrying out the public procurement activities as a best practice in order to promote the standard of living and economy of Sri Lanka to achieve the sustainable development of the country in line with the global requirements (World Bank, 2010; Biller and Nabi, 2013; Murray, 2009; Larson, 2009).

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SUSTAINABLE IMPLICATIONS OF BUILDING REUSE AND ADAPTATION

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ABSTRACT

Built environment products and processes are now biased more towards profitable markets while giving sustainability the first priority in achieving the same. Consequently, value has become one of the main concerns while seeking various cost reduction methods through sustainable implications. Building reuse is one distinctive way that reflects the aforementioned sustainability in multiple ways. The existing building stock in the UK does not support sufficient flexibility that can be used for future adaption. Demolition of those buildings and construction of new builds does not seem to be an optimum solution, unless it helps increasing the building redundancy. Thus, an effective and achievable solution is required to address this problem. Apparently, design for adaption and application of adaptable features from the initial stage of every new build seem to be the most sustainable way that can be endorsed with sustainable, flexible buildings that last long and resist the future potential changes.

The research has exploited qualitative methods to explore the aforementioned problem. The research itself is based on a case study of Liverpool City Centre. Ten Structured interviews were conducted to identify the sustainable implications of building reuse and adaptation while an Archival Analysis was undertaken to identify the patterns of building change of use and their ability to reuse. The findings illustrate that economic factors have immensely influenced towards building reuse and adaptation. The research findings would also help different stakeholders to make decisions on how reusable features could incorporate within the new building designs through sustainability.

Keywords: *Adaptation; Building Reuse; Sustainable Implications.*

1. INTRODUCTION

1.1. BACKGROUND AND RATIONALE

Reuse can be explicated as the second hierarchical level of popular waste reduction methods; 3Rs of lean construction (reduce, reuse, and recycle) (Craven, 2012). When it comes to building reuse, although it takes long planning process, it finally saves buildings from demolition and gives significant benefits in social, environmental and economic perspectives (Douglas, 2006). Not only that, but also it has the potential to serve end users rendering a higher aesthetic value (Wolstenholme, 2009). Brownfield reclamation is another term that can be used to describe building reuse leading to land conservation and the reduction of urban sprawl (Craven, 2012). However confusion about the equality of renovation and facadism on building reuse is still on the contrary (Egan, 1998). But as per the general sentiment, it has been identified that it is a historic building preservation other than tearing. If buildings are capable of reusing without rebuilding, all costs related to rebuild can be saved leading on to a positive direction of economy (Couch and Dennemann, 2000). Building reuse conspicuously illustrates the magnitude of building adaptability and convertibility (Carlson and Gardner, 2011).

Adaptability is the capacity of buildings to give occasion to ponderable change. Over the lifecycle of a building, change is inevitable, both in the social, economic and physical surroundings, and in the needs and expectations of occupants (Russell and Moffatt, 2001). The concept of adaptability can be categorised as;

- Flexibility, or enabling minor shifts in space planning;
- Convertibility, or allowing for changes in use within the building; and
- Expandability, (alternatively shrink-ability) or facilitating additions to the quantity of space in a building

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These can be achieved through changes in design and the use of appropriate technologies and materials. Ultimately, it gives a matured solution for most of the prevailing issues and challenges in construction industry over demolition and new constructions. A building that fails to survive upon the modern trends and demand while being inefficient both in technically and economically can be termed as a 'maladaptive' building (Russell and Moffatt, 2001).

Since environment, technological innovations, planning and policy issues, social requirements, political forces and economy are considered to be the predominant issues and challenges of construction industry; The buildings that fail to persist upon these issues and challenges would have to be converted by means of refurbishments otherwise would be demolished before they become waste as null and void (Kay, 2012). Most of the historical archaic buildings that currently exist can be considered as results of such conversions or refurbishments that were capable enough to exert with reuse. Majority of listed buildings in United Kingdom evidently prove this fact (Couch and Dennemann, 2000).

Buildings can be made adaptive and reusable by making changes in few different aspects such as; function that the building services for, volume which the building serve for certain amount of heads (population) and the sequence of hold that reins against internal and external forces. This can simply be termed as function, capacity and flow (Slaughter, 2000). Thus, the building can be adaptively reused for a purpose other than which it was built or designed for. Usually in a refurbishment, only the necessary sub-elements are replaced while the main structure/ shell is remained with minor or no changes. Therefore the durability of the focal structure is inevitably important (Russell and Moffatt , 2001).

In collateral to the rapid movement, aged buildings become maladaptive and unsustainable while reusing of them has had to deal with issues in terms of historic building conservation and heritage policies (Feildon and Bernard, 2003). Consequently, building's change of use has become one of the major issues in existing building stock in UK property market (Liverpool City Council, 2012). The information gathered in a recent research on building use change and its impacts have concluded highlighting the complaints on symptoms of "sick building syndrome" as a result of failure to adaption and continuation with those failures (McLennan, 2001). Demolition and building new doesn't seems to be economically viable and environmentally sustainable solution anymore (Douglas, 2006).

Nevertheless it is important to preserve those historic buildings as much as possible where 'reuse' is the distinctive approach to preservation of historic building and as well as preservation of existing resources. For, historic buildings represent the importance of social, cultural, environmental, economic and political perspectives of a nation (Feildon and Bernard, 2003).

1.2. AIM AND OBJECTIVES

The aim of this research is "to identify the sustainable implications of building reuse and adaptation'' through the objectives of identifying the pattern of building change of uses, investigating the factors that influence the aforementioned changes, exploring the adaptable potentials of those buildings and finally through identifying the triple bottom lined sustainable considerations of building reuse.

2. RESEARCH METHODOLOGY

The research is soundly based on a single design which is a case study design that enquires how functional changes of buildings have occurred over the past century and it ultimately urges the demand for adaptably designed buildings that resist potential future changes. Consequently, the case study promenades the functional change of built environment with respect to macro level.

The research process is designed with the aim of answering the research objectives (Naoum, 2012). The table below encapsulates the adopted research methods and the relevancies of them with each objective achievement.

Table 1: Research Objectives and the Research Process

Research Objectives	Adopted Research Methods							
	Literature Review	Informal Discussions	Archival Analysis	Semi-structured interviews	Web based discussion threads	Case study	Secondary data Analysis	Desk study
1. To identify how the uses and functions of buildings have been changed over their lifecycles (pattern of building reuse and change of use);	√	√	√	√		√		
2.To investigate the factors that influence for building reuse /change of use (reasons behind those changes);	√	√		√	√	√	√	
3.To explore the adaptable potentials of those buildings;	√	√			√		√	√
4.To identify the economic, social and environmental considerations of building reuse in terms of sustainability;	√	√		√	√		√	√

2.1. *PHILOSOPHICAL POSITION OF THE RESEARCH*

The study identifies 'building change of use' as one of main reasons for building obsolescence and investigates the potentiality of reusing existing buildings and its impacts towards sustainability. The study falls under applied research category which conducted as explorative research tradition, based upon 'pragmatism'. Nevertheless, explanatory descriptive traditions were also adopted in achieving third and fourth objectives. Since the study needs a clarification of sustainable parameters of building reuse including a cost-benefit analysis, an evidence-based, practical procedure was undertaken as an 'applied research'. Several approaches were used to collect data such as archival analysis for the case study, literature review, semi-structured interviews and secondary data analysis whilst the Triple Bottom Line (TBL) considerations for adaptability were identified through a desk study (Dainty, 2008). Coordination all these ultimately endorses a new set of knowledge connecting the theoretical insights into practical context with empirical verifications.

Since the study has exploited multi method approach to collect data, '***pragmatism paradigm'*** is the chosen philosophy in this study.

It is the ***Inductive theory*** to be employed in this research. The theories are derived from the aforementioned observations and explorations (Creswell, 2009). The application of Constructivism is to be taken with the inductive approach through qualitative methods. By the means of constructivism a theory can be formulated going through observations (Creswell, 2009).

As per the research aim and objectives ***qualitative*** is the best fit approach in collecting data placing the investigation under ***qualitative mono-design*** (case study).

2.2. CASE STUDY DESIGN

Case-based empirical study is used basically to form new fiction and establish theories or to confirm and expand the existing theories (Yin, 2003). Within the scope and delimitations of this study, ***a single longitudinal case study*** design is used to study functional changes of buildings in macro level which enables to extract the essence of an in-depth analysis.

The case study contrived to show that the building functional changes actually occurs over a particular period of time is, the Liverpool city centre. How that change effects on the overall sustainability is studied after identifying the factors behind those changes. Liverpool is a cultural city that comprises with an extensive heritage value with number of listed buildings that were reused from 17s. In that case the selection of Liverpool city centre represents the typical factors that were required to accomplish the objectives. The Liverpool city centre was chosen as the case study to thorough the consecutive pattern of functional change of buildings over past 100 years. The chronological trend enables to understand how uses of buildings have changed in a formal manner. The archival analysis morphologically allows witnessing that in macro level.

The unit of analysis is 'buildings' in which the trend of changes are studied confined by middle range (4 - 12 storeys) buildings. This unit of analysis was chosen because of the ease of comparability with the previous investigations where the unit is placed at the same level as those which are already placed in existing research phenomena.

The findings are finally interpreted with descriptive explanations derived from the comparing and contrasting strategy. In congenial to sustainability agenda the impacts of TBL sustainability are investigated in depth. In order to generalise the findings, semi structured interviews were used as a supportive tool.

Archival Analysis within the Case Study Design

Analysing historic data immensely supports in achieving research goal with evidence (Hall, 2010). As per Creswell (2009), the difficulties of archival analysis are, ethical approval to access archival data because of security and copy right reasons, format and quality of stored data (i.e. micro films, manually drawn maps) and technical deprivations. Thus, for this research, archival data catalogues for the past century was used obtaining the legal permission to access and extract the data with copyright permissions from Liverpool Record Office, Liverpool City Council and Liverpool Central library.

Both Goad maps and street maps were used in this case study. However, functions of buildings were not always displays in historic maps. As a solution for that, the micro films of Liverpool street directories were referred to identify the functions of each building. Street directories were gazette only after 1971 therefore one difficulty was there to identify the functions of buildings before 1971. For that, a comprehensive literature search was carried on. Some points were clarified via informal discussions with a development control of Liverpool Record Office.

2.3. DATA COLLECTION METHODS- STRATEGY OF INQUIRY

2.3.1. PRIMARY DATA COLLECTION METHODS

Conducting Interviews was the predominant primary data collection method of this study. Participants were selected in multi-disciplinary fields related to the building reuse (ex; architecture, engineering, planning, policy making and regulations, sustainability, procurement, construction management, facility management, quantity surveying and academician). Knowledge of the participating residents and experts can be relied upon the subject area as they can be considered as witnesses for the functional change and people who have practically experienced the change over time (Flick, 2006). A semi-structured questionnaire was employed as an instrument for data collection in this empirical study.

The audio clips were then transcribed and those were analysed via qualitative data analysis (QDA) computer software package NVivo. The data analysis was then used to develop a grounded theory. Grounded theory is a theory that was derived from data, systematically gathered and analysed through the research process.

2.3.2. Secondary Data Collection Methods

An extensive literature review is speculated all over the research supporting each and every part of it. Initially, this was used to manipulate the formerly researches undertaken on the same area to perceive the basement for the study (Naoum, 2012). The reliability and relevancy of those were secured as all the secondary data sources were obtained through Liverpool John Moores University electronic library catalogue databases plus the university libraries, learning resource centres and Liverpool central libraries. The most of the secondary data sources were extracted from university learning resource centres while the sources from central libraries were obtained from the official membership of the respective libraries.

The archival records, historic maps, special books and documents were obtained from the Liverpool Record Office archival unit. Micro films were another good source of data for preserved archival records which were again available at Liverpool Record office.

A thought process review with related literature is illustrated in Figure 1.

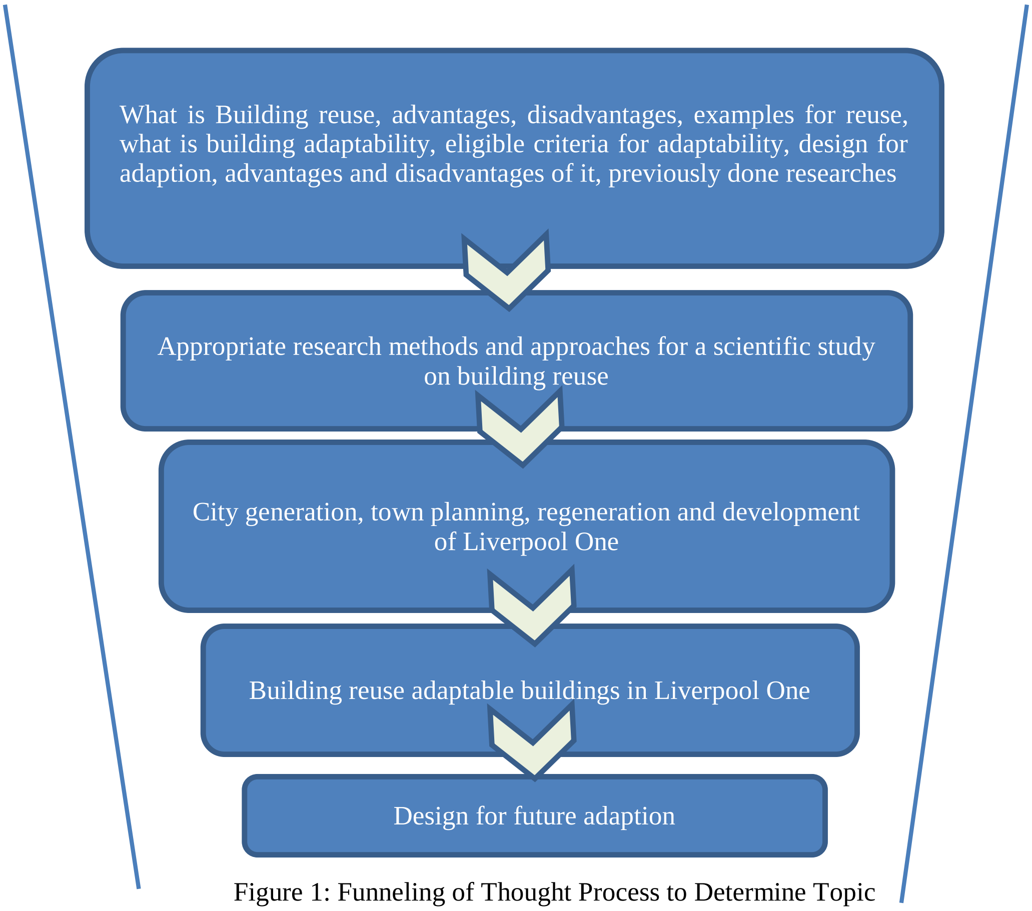

Figure 1: Funneling of Thought Process to Determine Topic

Apart from that, already collected data are properly refined and categorised as their relevancies and information are produced that can use as inputs to the analysis by a 'desk study' (Creswell, 2009).

Numerous documentary data were used for this investigation. Archived reports, statistical records, building regulations, use class warranties; sustainability agenda, listed building consents, planning permission guides, etc. were some of them.

Documents/audio-visual materials are also employed as data taken from record office. Historical data, ownership transfer, tenant change, functional changes are examined through the data collected from Liverpool Record Office. The archive catalogue and relevant documents obtained from the Archaeological Department are also to be used in the research.

3. Scope and Delimitations

In terms of 'use', the life span of a building can be prolonged with the features made in the initial design stage. Considerations on the construction stage are not covered by the research.

The research observation case study itself is practically and theoretically limited to the Liverpool city centre- L1 zone where the resulting outcomes are considered as a representative of the adaptive building reuse in aggregate of United Kingdom. The study is focused on the sequential changing pattern of reused buildings over the past 100 years where the selected case studies; buildings are precisely focused on the change of use. In that case, four number of use denominations; commercial, residential, office and retail are focused by virtue of similarity in their use, design, procurement and economic deliberations.

The selected case study is consisting of buildings that are limited to 3 – 12 stories (middle rise range) because the more the high rise, more tendencies to allocate higher design loads on foundations and different design parameters for adaptability. Very High-rise and buildings with two or less stories structures or buildings were not considered. Listed buildings are also not covered within this research scope. Majority of buildings in the selected cluster for the case study however are retail and office buildings.

4. Literature Review

4.1. Rationale

Over the last two decades, sustainable development and corporate social responsibility were two of the main discourses driven by global pressures. On the other hand, the global economic crisis is another hot topic widely perceived as the biggest barrier for the performance of afore-mentioned two factors. The UK construction industry frequently attracts hostility among the local community and general public due to its disruptive impact arising from the built environmental activities (Moore and Rydin, 2008). In that case the development of sustainability and CSR has been the best response being a solution for global warming and financial crisis as well. Since transition of economies is somewhat beyond the control of individual perspective, every organisation should have a strategy to respond the challenge of meeting ethical, corporate social responsibility and sustainability-related responsibilities in recessionary times (Pitt, *et al*., 2007).

The current global economic downturn provides a unique opportunity to re-assess the sustainability of construction projects and develop more innovative practices (Hobbs and Mansour, 2009). With the recent declining economy and the dynamic regression of land markets people started to think that the trend for green is dying, but projects that promote reuse have proved that greener buildings have been a perfect solution endorsing more for less cost supporting the economy as well (Hobbs and Mansour, 2009).

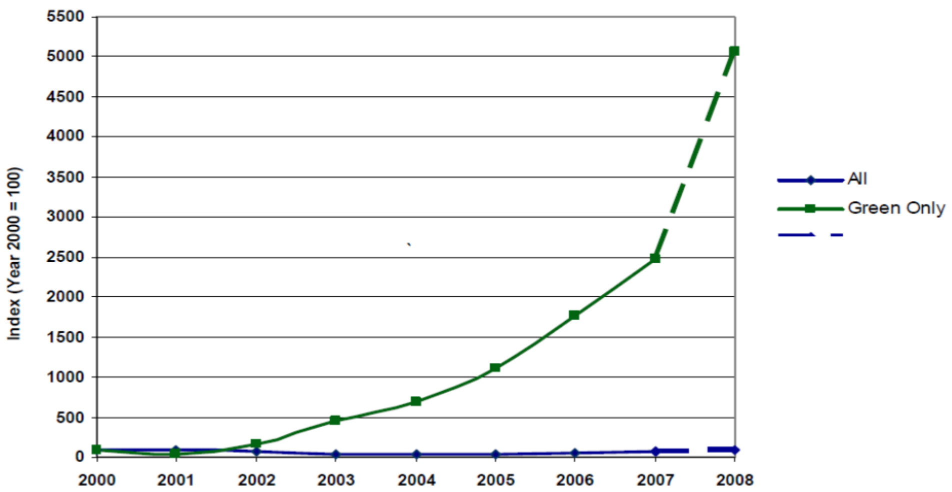

Figure 2: Green vs. Non-green Buildings Growth in Europe
Source: RREEF Research (2009)

Despite this economic down turn, a tremendous growth in sustainability proves the greater potential for green buildings and sustainable solutions in the near- and long-term.

Hence, reuse of buildings and designing buildings that are endorsed with adoption potential are generally less cost consuming than conventional new buildings in terms of cost saving, good will of environment and greater demands with higher rent premiums for such properties (Murphy, *et al*., 2010). In fact, that can be a competitive advantage for global economy.

Construction industry is a major contributor for the pollution not just in the UK but also in the worldwide environment (Nieto, 2009). Built environment activities uses approximately 6 Tonnes of material for construction each year for every woman, man and child in UK (DTI, 2006). DTI further revealed that construction sector generates 92 MT of wastes per year, of which 13 MT are unused raw materials (Cabinet Office UK, 2011). Apart from that, 90% of non-energy materials extracted in the UK are supplied as construction materials and, the construction, occupation, maintenance of building and consumes 42% of all energy and generates around 50% of all UK carbon dioxide emissions, thus contributing to climate change. The construction industry is also a major consumer of natural resources causing natural material depletion. Being some of the impacts cause by construction industry in UK, have deleteriously effect on every aspect of the environment. In that case, it is undoubtedly proven that built environmental activities hold major part of the responsibility for most of the dangerous consequences cause lately.

4.2. EXISTING BUILDING STOCK

The contemporary built environment facilities are always a representation of a local cultural capital plus social, environmental and economic status of a particular area. However failure to withstand and adapt the TBL changes is a major reason to decrease this value of existing building stock. This has practically proven since majority of existing buildings built in mid-eighties are designed focusing on a single function within the intended life span. In that case the existing building stock has now faced drifts of challenges that include;

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- Having buildings with long lifecycles but they are used for functions with short life cycles;
- As some stocks no longer meet current requirements, huge amount of vacant building stocks have been generated evoking an issue of building redundancy;
- Rapid change of user demands has become higher than the possibility for the existing buildings to be adapted in accordance with the changes;
- Tremendously biased trend for sustainable development in the built environment

These challenges conspicuously show that the existing building stock has got a greater need of a positive change. The buildings and their elements should be modified in terms of function, capacity and flow (Slaughter, 2000). The table below shows the ways that buildings can respond to the typical changes.

Table 2: Responses of Buildings to Changes

Type of Change	Category	Responding Factors
Function	Upgrading existing functions	Higher performance levels that require different components/ processes
	Incorporate new functions	New facility performance objectives that require new components/ systems
	Modify for different functions	Different objectives from change in usage class that require different components, systems and/ or processes
Capacity	Change in loads/ conditions	Higher expected performance under specific load conditions

Type of Change	Category	Responding Factors
	Change in volume	Increased requirements for operable space per usage class
Flow CIOB Subsection	Change in environmental flows	Higher/ different performance requirements for internal or surrounding environmental conditions
	Change in flow of people/ things	Different performance requirements for passage, movement or organisation of people/ things within/ into the facility

Source: Slaughter (2000)

The existing building stock is mostly accordance with the current framework for change of use in planning that is contained in the Town and Country Planning (Use Classes) Order 1987 (as amended) and the Town and Country Planning (General Permitted Development) Order 1995 (as amended) (Research Limited, 2012). Therefore any modification that is executed should undergo these congenial planning acts. However, upgrading maladaptive buildings to fit intended adaption is not always economically viable and technically justifiable. On the contrary, demolition may also not sustainable. Apparently, buildings designed for a single function is also somewhat practical economic solution in most business case scenarios (Jiune, 2011).

4.3. *A Need to Design New Buildings for Adaption*

The remedy for aforementioned issues and challenges are not only for existing building stock, but also for the buildings to be designed. Failure to design adaptable buildings will definitely result huge amount of obsolete buildings and ultimately increases building redundancy. Since the current building stock slightly facilitates this fact, an eager need has been evolved to design buildings for adaptions. The inflexibility of the original design seems to be the main cause for this, leading the buildings to be remaining vacant, demolished or reused with major renovations (Jiune, 2011). Having a stock of excrescent buildings is a threat to the growth of economy as the owners are bonded to pay taxes even though they do not emanate income and as well as a detriment for the social enhancement. On the other hand, overthrowing and constructing new builds is neither economically nor socially acceptable and does not consort with the sustainability too (Manewa, 2012).

Buildings designed to maximise the potential for adaptation confessedly accommodate different uses that are required in accordance with the change of market, cultural and political trends (Webb, *et al*., 1997).

4.4. *Building Reuse/ Adaptation and their Sustainable Implications*

Certain built environmental communities define Adaptive Reuse (AR), or Re-use, as "the process that adapts buildings for new uses while retaining their historic features." (Davison, *et al*., 2006) A more accurate definition to AR is given as prolong the period from cradle-to-grave of a building by retaining all or most of the structural elements and as much as possible of other elements (Latham, 1994). In that case, it is not only the buildings of historic significance can be infused with new life but also the sundry buildings (Barlow and Gann, 1996).

In modernity, the aspiration to preserve historical buildings emerged in many Western countries out of various romanticist, nationalistic, and historicist streams (McLennan, 2001). Today, the exigent factor of extending the life cycle of a structure has been one of the major goals of sustainability too. Being a solution to building redundancy and sprawling, it immensely preserves virgin materials while conserving energy as well (Pirlon, 2004).

Advantages of Building Reuse

Most of the historical buildings are located in the centres of cities and in collateral to city developments these buildings remain as heritage-listed buildings adding a societal value (Feildon and Bernard, 2003). Adaptive reuse helps to extend this value. Another fact that clearly stands out is old buildings are often made of specific construction techniques and materials that the modern industry lacks of. In that case, the majestic nature of these buildings can be used to enhance the attractiveness towards clients as per the requirements of new tenants (Couch, 2003). Apparently, the savings in terms of cost, energy and environment and the contribution to overcome the global issue 'climate change' is the biggest benefit that can be gained as a result of building reuse (Hall, 2010).

Table 3: Summary of Different Benefits of Adaptive Reuse

Category	Description
Archaeological Motives	Architectural evidence for present and future generations
Aesthetic Appreciation	-Visual Amenity; the subjective enjoyment society experiences from its visual environment, its complexity and richness -Regional and particular character: reuse reinforces local identity -Cultural value: adds to richness, eclecticism, serendipity in built environment
Economic	Assess if cheaper than demolition, long term energy savings waste management cost of demolition
Function	Creative programming of existing building
Psychology	Involves the poorly studied psychological experience relative to drastic change Vs. gradual evolution of the built environment
Environmental	Retention of the original building's "embodied energy", lower greenhouse gas emissions. Reuse of buildings usually involves a saving of approximately 95 per cent of embodied energy that would otherwise be wasted
Social	Maintain the heritage significance of building increase liveability; provide the community with new housing and commercial property opportunities.
Promoting innovation	Emerge creativity in engineers, designers and architects

Source: Latham, Creative Re-use of Buildings I and II. Donhead, Dorset (2000)

Barriers to Adaptive Reuse

The biggest barrier for adaptive reuse is the unsuitability and unsustainability of some old buildings and sites (Couch and Dennemann, 2000). In that case, the costs for modifications can be higher than a new build. Unviable circumstance that does not suit the current building codes is another fact. (Ex: the contamination of asbestos in old sites). Difficulty in obtaining planning permissions including planning and policy issues is also can be defined as a draw back for AR.

Sustainable Considerations of Building Reuse

The balance between environmental health and economic health is secured by the means of energy efficient designs and materials (Kesik, 2013). Communities always have much to gain from historic buildings as adding value to their lives through pursuit of sustainable development. Avoiding the wasteful process of demolition and new constructing admittedly saves energy while benefiting the social advantages of recycling (Pirlon, 2004). Sometimes, adaptive reuse is the best way that the building's structure is cared in order to gain better use of the building itself. Where a building can no longer function with its original use, a new use through adaptation may be the optimal way to preserve its heritage significance while contributing to sustainability. However, some governments have made policies when adapting heritage buildings to minimise the impact on the heritage value as follows;

- Discouraging "facadism"- removing internal parts and retaining its facade
- Behest the new work to be contemporary and not to be poorly imitated tasks that makes harm to the original historic formation
- Recommending a new use for the building that is compatible with its original use.

Reuse of materials and resources, lesser energy involved, need of lesser labour and machine power certainly impact on a country's economy by minimising the expenditures on new builds (Simons, 2009). The monetary funds reserved for new constructions can be saved therefore.

5. CASE STUDY

Qualitative data are basically analysed to distinguish between several themes and disclose the substances that are consisting of expected characteristics that addresses the set objectives (Kirk and Miller, 1986)

Data is **primarily** collected by aforementioned case study observation and interviews. Thereupon, the collected data is analysed and interpreted through following types of analysis methods.

Table 4: Research Objectives and the Research Process

Strategy of inquiry	Research method	Supplements
Case study	Archival analysis, content analysis	Manual
Semi- structured interviews	descriptive thematic analysis	NVivo.

The selected cluster for the cases study is the Liverpool City Centre focusing on a macro level diagnose.

5.1. HISTORICAL CONTEXT OF BUILDING CHANGE OF USE IN LIVERPOOL

Liverpool is a city which is incorporated within the Metropolitan County of Merseyside with a wealth of historic value goes 800 years back since it's founded and recorded as borough in 1207 (Webb, 2007). Liverpool has the greatest density of Grade- I listed buildings outside London and whole famous sky line.

5.2. CASE STUDY INITIALISATION

Single case study was studied to explain the typical changes of buildings over a period of 100 years. The city of Liverpool focused on the change of use of buildings within a relatively larger geographical area (macro level).

Though number of factors act as obstacles, economic matters and planning and policy issues are considered to be the most likely limitations to implement building reuse and change of use solutions in the built environment. It is important to reuse buildings in a city like Liverpool which has historic/character value of buildings so that the historic buildings are preserved for more generations ahead; as well as the culture and heritage is also preserved. Thus, this study was designed to explore all three TBL factors including economic and political considerations for building reuse.

Over the last 50 years Liverpool has undergone more economic restructuring and urban change more than any other city in Britain. For whilst Liverpool represents an extreme case with respect to the rate of urban change, economic, social and environmental pressure compared to those found in other cities (Couch, 2003). Liverpool city Centre has had to adapt more than most, its hand being forced by an enormous economic decline back in the years, post war period (Wilkinson, 2011).

The area selected for this study is the triangle surrounded by Paradise Street, Church Street and Hanover Street. The reason the select this triangle was this was the popular 'Paradise Triangle' that was a core zone pinpointed labelled as the 'principal development area' (Littlefield, 2009). Historical Street maps, Goad plans, street directories were used to capture the changed occurred to buildings over last century. Maps were analysed (archival analysis) to identify the changes and the reasons behind those patterns. Changes are clearly noted in the matrix of a chronological order classifying the building uses as social, commercial, industrial, residential, leisure/ recreational and open / vacant. Residential included detached and semi-detached houses and apartment blocks. Commercial comprised offices, banks, public houses, hotels and retailers. Industrial included buildings for manufacturing and warehouses. Social covered schools, churches, clubs, hospitals and buildings that were built for the purpose of maintaining community wellbeing. Leisure included parks and other recreational facilities. The highlighted changes were mainly in terms of use and size. However, this study predominantly focuses on the change of 'use' compared to other types of changes. Functional transformations are investigated through a typo-morphological analysis.

The reachable historic maps and archival documents/ micro films were collected from Liverpool Record Office (archaic maps and records) and Liverpool central library (recent maps not older than ten years). Thus the archival analysis is to realise the macro level of building chronological change.

Historic maps to a scale of 1'' = 88ft/ 1:1000 for the years 1795- 2012 were used to study the pattern of building use change over the years. Among them a critical functional changes were identified in years 1880, 1924, 1988, 2004 and 2010 which are illustrated in the figure below. The factors behind these transformations were also studies with the investigation of remaining maps. Direct visit observations were also made to clearly identify the transformation from the older building to the current status. The buildings with no change are indicated in grey colour.

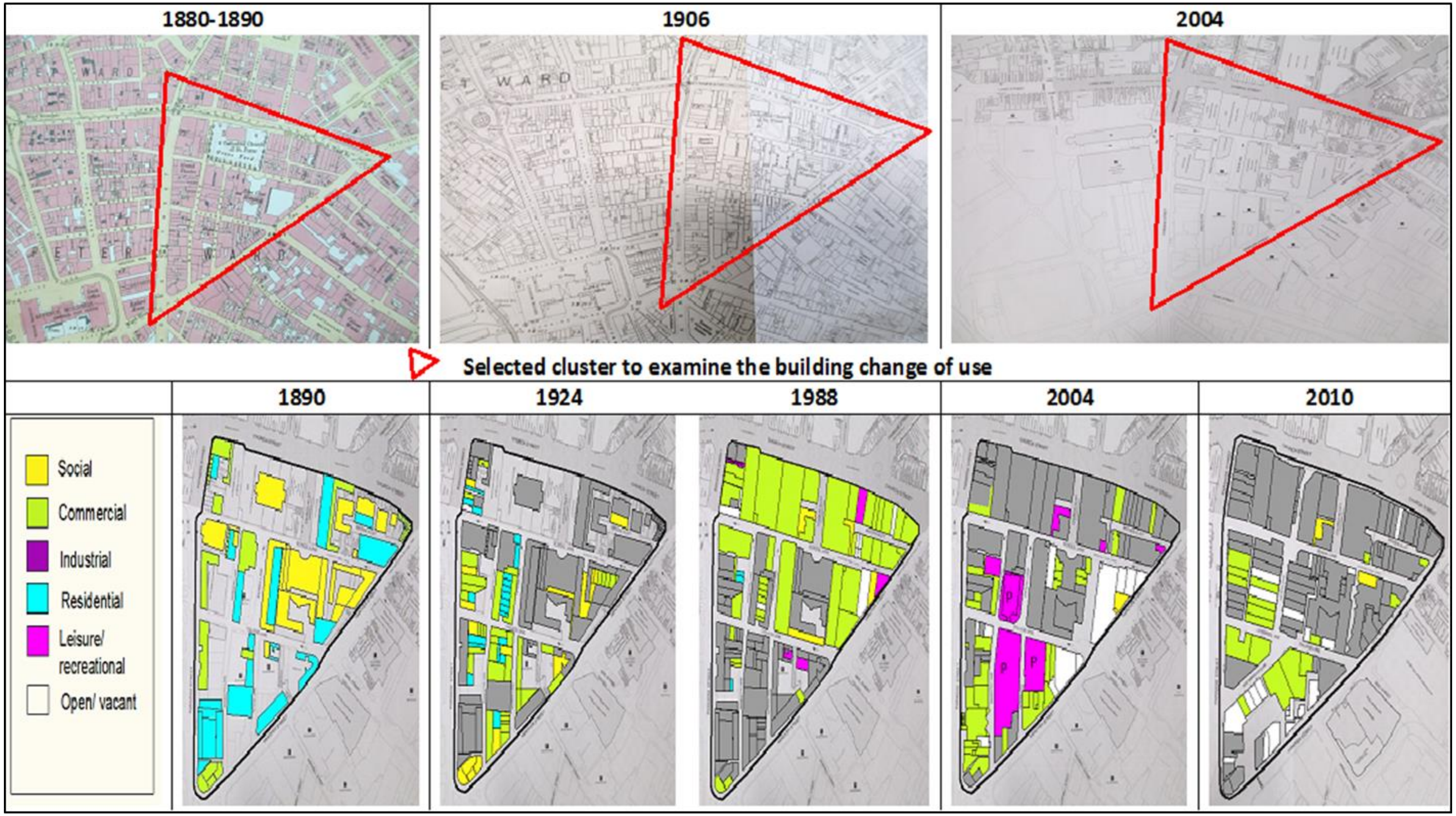

Figure 3: Macro Level Change of Use in Buildings
Source: Old Ordnance Survey Maps, Street Maps and Goad Plans of Central Liverpool, Liverpool Street Directories; Liverpool Record Office, Archival

5.3. ANALYSIS OF THE CASE STUDY

Figure 4: 1765

Many of the agricultural fields and bare lands were developed for new buildings and their associated infrastructure networks. The city was not much packed but the commencement of few industrial buildings and residential buildings has been occurred. Compared to the other typologies, social buildings were the majority (Routledge, 1988). Few semidetached houses were built along Manesty's Street and School Lane. Few commercial stores also can be seen which were connected with the shipping industry. A scattered appearance of buildings has been there in this era. The St. Peter's Church, Bluecoat and a pub house can be identified as social buildings.

Figure 5: 1890 (Base plan)

The number of buildings within the cluster has been increased taking the advantage of bare lands. This was the era where Liverpool suffered from high population. As a solution, more semi-detached houses, terrace houses were built with lesser facilities. The number of pubs has also been increased with the development of Cain's Brewery business. Few commercial buildings have built, yet fully connected with the shipping industry. The bluecoat charity school was converted in to a hospital. Grand Theatre was made at the start of the school lane converting the pre-existed semidetached houses.

Figure 6: 1924

Many changes have occurred at this time. Few buildings which were used to be residential were converted in to commercial (Research Limited, 2012). The impact of world war is also immensely effected the functional change of buildings. A considerable spatial expansion can be seen to make residential buildings to fit for the demanding population. Few hotels were also built. The blue coat hospital was again converted in to a school of architecture. The athenaeum remains with several inner renovations.

Figure 7: 1988

Many changes have occurred at this time. The Parish church has been demolished and many commercial buildings have built. Residential areas have been utmost reduced and they have been converted in to commercial areas. More space has been allocated for commercial buildings, enabling the city to take the place of a commercial hub by this time. Post war rehabilitation can be seen in positive perspective. Many extensions and new construction have been undergone. Few vacant spaces can be seen as obsolete buildings as a result of war damages. This was the time when unemployment rate was highest of 26% (Couch, 2003).

Figure 8: 2004

More ground and underground parking area were created. The vacant area has been increased. More retail stores were created with extensions and reuse of existing buildings with conversions (Royden, 2012). The blue coat building has been further refurbished to have few retail spaces too. Most of the retail buildings were carried on with the same function but with a change of owners (i.e. CandD store was then owned by NEXT and HMV). The old John Lewis was moved to the corner of the triangle.

Figure 9: 2010

Many changes were undergone since 2004 to 2010 with the Paradise Street development which were not externally visible because of the façade retaining but numerous internal changes (Madsen, 2009). A remarkable growth in commercial, social and open spaces can be identified in 2008. Since city Centre is a commercial hub, more than half of the area is converted in to commercial space while the remaining is comprise with social and open spaces (Moscardini, 2008). Residential spaces are very few which were also owned by Liverpool city council. The area which was vacant still remains same while adding more vacant area proving the problem of 'building redundancy' in the city.

By 1888, all functional categories were appeared to be in L1 area. With an in-depth analysis, the cluster seems to have started to commercialise from 1980 onwards. A major redevelopment can be seen by 2006 with the Paradise Street development (Reid Architecture, 2005). Apparently, residential buildings were totally shifted away from the cluster and more commercial and social buildings were accommodated. The residential buildings' failure to contribute to the city economy most of them were required to convert in to office or public house spaces. The dramatic growth in population has immensely impacted on this. This is the key factor identified as a driver for most of the spatial expansions, sustainable persuasions, social and wellbeing improvements. Apart from that, political and legislative changes, sustainable concerns and trends, change of user demands time to time have also impacted on these changes.

The establishment of bank in early 19s shows the stability of city in terms of monitory transactions. HSBC and Lloyd's banks are vital among them. A huge contribution to the economy has been made by the three anchor stores of the city which were chronologically sentenced to different changes since early 80s. However it seems that many buildings have reused over and over again for different purposes while few has demolished and few remain redundant too. The adaptability of them was positive in to a certain extent unless the rate of replacement and refurbishing is not exceeded 50% of the entire work (Parker, 2012).

Additionally, a growth in social and leisure buildings within the cluster also can be seen. With all these, it is notable that the shipping industry of Liverpool continued from the beginning apart from few pauses in early 18th and 10th centuries, which is another key contributor to the city attractions as well as economic stability. Thus, economic, social and environmental considerations are identified behind these changes and they can be assisted when DFA and the process of reuse.

6. INTERVIEWS

In addition to archival analysis of building change of use 10 interviews were undertaken among the academics and professional experts to identify the impacts of those changes. Interviewees were asked to respond to a set of structured questions and the data was analysed through NVivo software. A summary of interview data is included in the conclusion.

With the case study, it is conspicuous that many changes have occurred over the past 100 years with respect to social, industrial, residential and commercial buildings. Those changes can be small with additional improvements (no functional change), large changes with major refurbishments (no functional change), large changes (functional change) or demolition. It also identified that the possibility of converting old building to newer building with a functional change or same use is in a higher rate. Evidences were given that successfully undergone through such processes. Population growth, manufacturing and industrial growth, rate of higher education, recessions have highly impacted on these generic changes. Planning and policy matters also highlighted among them. Eventually, it can be concluded the case study by asserting that, building change over time practically occurs and the functional change is prominent among them. Some aged buildings are comprised with a higher potential to adaptability.

The first objective was to identify how the uses and functions of buildings have been changed over their lifecycles (pattern of building reuse and change of use). The case study research design employed in the study has conspicuously identified that the building change has occurred in past 100 years with a determination of the pattern of change in macro level. The second objective was to investigate the factors that influence for building reuse /change of use (reasons behind those changes). The same case study analysis has been capable of identifying the factors behind those changes linked with the historical context and background to the case study. Secondary data analysis helped to generalise the findings. Growth of population, education status, policy and legislative matters, interference of government, recession and growth of other sectors (industrial, commercial and educational) over the last century were the closest reasons behind these.

Exploring the adaptable potentials of the aforesaid buildings was the third objective and a comprehensive narration was given on adaptable buildings and their implications toward practical application while exploring the adaptable potential of the buildings within the selected cluster (case study) in order to achieve that. The supportive arguments were given by different participants in interviews. Different time periods during the last century proved the current need for designing new buildings towards potential adaptations. Whilst, improving the possibilities for extending the functional lifespans of buildings were deeply discussed with the incorporation of both secondary and interview data.

The final objective was to identify the economic, social and environmental considerations of building reuse in terms of sustainability. Data collected from interviews immensely contributed to identify the TBL sustainable considerations of building reuse while existing literature strengthens the dictum.

7. VALIDITY AND RELIABILITY

"Reliability and validity are tools of an essentially positivist epistemology" (Braun and Clarke, 2006). Riege (2003) explains reliability as the extent to which the research results are decisive over time and the selected sample should therefore represent the accurate percentage of total target population. Kirk and Miller (1986) discusses about three types of reliability in a quanitative study as follows;

- the degree to which a measurement, given repeatedly
- the stability of a measurement over time
- the similarity of measurements within a given time period

A high degree of stability indicates a high degree of reliability, which means the results are repeatable. The validity in a quantitative study as Golafshani (2003) explains is whether the study actually measures that which it is intended to measure or how truthful the results are.

Reliability in a qualitative paradigm is always based on Credibility, Neutrality or Confirm-ability, Consistency or Dependability and Applicability or Transferability (Kirk and Miller, 1986).

The maps used for the case study were the original maps derived from the archival department of Liverpool record office and Liverpool central library. The data related to the historical context were also derived from same places archival catalogues and books. Census and statistics were obtained from websites; Office for National Statistics, UK. Analysis was undertaken without any changes to their originality. The validity and reliability of interview data were stated in chapter five.

8. CONCLUSIONS AND RECOMMENDATION

8.1. OBJECTIVE ACHIEVEMENT

The first objective was to identify how the uses and functions of buildings have been changed over their lifecycles (pattern of building reuse and change of use). The case study research design employed in the study has conspicuously identified that the building change has occurred in past 100 years with a determination of the pattern of change in macro level. The second objective was to investigate the factors that influence for building reuse /change of use (reasons behind those changes). The same case study analysis has been capable of identifying the factors behind those changes linked with the historical context and background to the case study. Secondary data analysis helped to generalise the findings. Growth of population, education status, policy and legislative matters, interference of government, recession and growth of other sectors (industrial, commercial and educational) over the last century were the closest reasons behind these.

Exploring the adaptable potentials of the aforesaid buildings was the third objective and a comprehensive narration was given on adaptable buildings and their implications toward practical application while exploring the adaptable potential of the buildings within the selected cluster (case study) in order to achieve that. The supportive arguments were given by different participants in interviews. Different time periods during the last century proved the current need for designing new buildings towards potential adaptations. Whilst, improving the possibilities for extending the functional lifespans of buildings were deeply discussed with the incorporation of both secondary and interview data.

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8.2. IMPLICATIONS OF THE RESEARCH FINDINGS

This study emphasises the trend towards reuse of existing buildings and also reckon a need for designing new buildings to be future proof. The understanding of social, economic and environmental considerations (benefits and disbenefits) of building reuse and adaptable buildings leads to encourage the DFA process and solely building reuse. Moreover, it helps clients/owners/ developers on their decision-making towards building adaption. The findings suggest more buildings would be reused while more adaptable buildings would be designed if there were a proper framework/ standardisation, easily reachable regulations/policies, improvement in adaptable/ reused buildings' value and rent, comfortable planning regulations, a positive change in the industry towards adaptability and, optimum use of lifecycle cost analysis.

There are both costs and benefits related to DFA and building reuse. But a properly clarified cost benefit analysis, with the help of WLC have the potential to assist the decision making process on the same. Thus, this research benefits for many stakeholders such as owners/ clients, developers/funders/investors, planning and policy makers, end users and the general public.

8.3. CONTRIBUTION TO THE CURRENT KNOWLEDGE BASE

The research findings strengthen and support the credibility of the existing knowledge base while embossing the fact that a trend for building change of use and building reuse is practically occurring. Additionally, the research also confirms the TBL sustainable considerations in building reuse and DFA while emphasising the most influential design parameters as spatial flexibility such as floor to ceiling height and structural stability.

8.4. RECOMMENDATION

Adaptable buildings are now identified as a leading requirement of the UK Government even though it is a shortfall of most parts in UK. A positive trend towards building functional change evidently proves that fact. Designing buildings for a long structural life and short functional life seems to be balanced need in terms of sustainability. It's economic unviability and social unacceptability and environmentally unsustainability is also on the contrary, as it is comprised with both benefits and disbenefits. However, long term decisions on building.

Reuse and DFA can be achieved through in-depth investigations and WLA. Therefore modern construction industry led strategies require considering ways of ensuring adaptable features are included at the earliest possible phase of design. Literature reveals the initial capital cost of adaptable building as a critical challenge, although the cost in-use is comparatively low with time in adaptable buildings. To recapitulate this study is solely a mean of clarification towards long time decision on building reuse and design for adaptable buildings which is now achieved to help the aforementioned stakeholders to have a think on with insight shrewdness.

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SUSTAINABLE RESPONSIVENESS FOR RECESSIONARY EFFECTS IN THE CONSTRUCTION INDUSTRY: A STUDY ON APPRAISING BENEFITS

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ABSTRACT

The construction industry is a significant source of revenue generation to the economy, contributing more than 9% of the Gross Domestic Production (GDP) in Sri Lanka in the year 2012 according to the Central Bank statistics. Thus, the construction industry is concurred a positive relationship with the cyclical economic fluctuations. Consequently, adverse economic conditions directly affect the industry and resulted in stagnation. In response to the recession, the construction practitioners adopt various strategies. However, the recession responsiveness must be aligned with the concept 'sustainability' which concerns beyond the profit oriented short-termism.

Hence, the aim of this research study is to investigate the benefits (Strengths) of sustainable responsiveness to minimise adverse effects (Threats) in the construction industry during the recession. An expert interview survey was conducted among different construction stakeholders to obtain multi rational perspectives. The survey analysis derived that social benefits associated with sustainability have contributed mainly to gain the benefits over recessional threat. However, many of the statements were neutralised stating that 'Sustainable benefits sometimes minimise recessional threats'. Henceforth, it can be concluded that the sustainable strategies favourably respond the recession to mitigate recessional threats and direct long term strategic establishment. In addition, public awareness is essential to gain the sustainable benefits. Finally, it is recommended to be aware of the recession adhering to the opportunistic way forward through sustainability rather beware of its appalling adverse effects.

Keywords: *Adverse Effects; Construction Industry; Economic Recession; Sustainable Benefits; Sustainable Responsiveness.*

1. INTRODUCTION

The Great Depression in 1929 was an episode of severe recession, which was attracting volumes of studies explaining the recession. Keynesianism, Monetarism, Laissez-faire philosophies and Rational Expectation were some of the theories addressed the causes and effects of recession. The economic recession during the years 2008 and 2009 is considered as the most devastating economic event since the great depression (Papademos, 2009). Growth in advanced economies slowed a contrary weight down by domestic fiscal adjustment, tight credit conditions and sluggish labour market, thus leading to a fragile and unstable economy (Central Bank of Sri Lanka [CBSL], 2012). Further, CBSL (2012) explained that the market confidence in international financial markets was deteriorated by the European sovereign debt crisis led to heightened volatility in capital flows of Asian economies. Thus, it signalled the impact to Sri Lanka which is a developing country in Asian continent.

The consequences of the recession derived visible effects in the construction sector, mainly in the form of postponing or abandoning of contracts. In the worst case scenario, construction companies may end up in even bankruptcy due to financing difficulties. Hence, contractors adopt various recession responsive strategies to realise firms' objectives of survival and development. However, many survival strategies innovated are reactive and focuses on economic perspective. Hence, the recession responsiveness must be aligned with the sustainability for a long term proactive implication.

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Though, the sustainable responsiveness is suggested to cure the appalling effects of the recession in the construction industry, the assessment of the benefit of sustainability is a current lacuna. However, competitive advantages of sustainable responsiveness have not clearly addressed in the existing literature. Hence, the benefit attributed in the concept sustainability must be considered to ascertain the benefit of sustainable responsiveness during the recession. Thus, this paper aims to:

- To identify adverse effects in the Sri Lankan construction industry during the economic recession
- To identify sustainable responsiveness to mitigate the adverse effects of the recession
- To evaluate the benefits of adopting sustainable responsiveness to minimise threats

The paper structure begins in the following sections. Firstly, an overview of economic recession, critical adverse effects faced by Sri Lankan construction industry during the recession and sustainable responsiveness were ascertained through the existing literature findings. The next section presents the research methodology followed by data analysis to achieve the aim of the research. The paper finally presents discussions and conclusions of the research study.

2. ECONOMIC RECESSION AND ITS IMPACT TO CONSTRUCTION INDUSTRY

2.1. OVERVIEW OF ECONOMIC RECESSION

The economic recession which shaken the global economy during 2008 and 2009 is considered as the most devastating economic event since the great depression in the 1930s (Papademos, 2009). According to recently published highlights of recent economic developments by the Central Bank of Sri Lanka (CBSL, 2012), growth in advanced economies slowed a contrary weight down by domestic fiscal adjustment, tight credit conditions and sluggish labour market during the recent past. Thus, According to National Bureau of Economic Research (NBER, 2012), the recession is defined as,

> “The economic recession is a period of falling economic activity spreads across the economy, lasting more than a few months, visible in real GDP, real income, employment, industrial production, and wholesale-retail sales”.

The SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis is a strategic planning tool, identifying internal attributes and external factors. Opportunities and threats present in the external environment in the line of achieving strategic objectives considered comprehensively for the reason that the recession is a generic systematic risk (Chen and Brunski, 2007). Thus, dynamic environment can be critically analysed under the threat component.

The threats include the external shocks in many economies as globalisation continues to dissolve boundaries across the world. Further, CBSL (2012) explained that the European sovereign debt crisis led to experience heightened volatility in capital flows of Asian economies. Consequently, there is a risk that the mature economies being highly leveraged for a lengthy period, leading to a fragile and unstable economy (Baldauf and Hubbard, 2011). The key factor which permeates all policy levels during the great depression is the fall in prices and nominal GDP and then resulted in bank failures by forcing many debtors into default (Alcidi and Gros, 2010). However, according to Ren and Lin (1996) earlier recessions were provoked by high inflation as the fundamental factor, so there is a mismatch in views of fall in prices by Alcidi and Gros (2010). Nevertheless, consenting to Killingsworth (2012), severity of the recent recession was the increasing of unemployment mainly in manufacturing, wholesale and retail trade, and construction sectors. CBSL (2012) reasoned for this particular demographic is a common indicator of poor labor-market conditions. As deleveraging continues, the revision of capital market indices caused sharp fluctuates in market asset prices due to repositioned investment portfolios by foreign investors. Consequently, depreciations of currencies, pressures on domestic asset prices, exchange rates and external reserves are further significant causes (ADB, 2009). According to ADB (2009) the global financial market has stressed down the local market in developing countries.

2.2. ADVERSE EFFECTS (THREATS) IN THE CONSTRUCTION INDUSTRY DURING THE RECESSION

The construction industry plays a vital role in the national economy, and gets affected by macroeconomic fluctuations. In Sri Lanka, construction industry contributes 9.39% of GDP in the year 2012 (CBSL, 2012). Thus, the global recession caused by the financial crisis having an impact on the real economy and signs are visible in the construction sector, mainly in the form of postponing investment or abandoning of proposed contracts (European Construction Industry Federation [FIEC], 2009). Furthermore, construction companies face financing difficulties and in some extreme cases, even bankruptcy (Nistorescu and Ploscaru, 2010). Additionally, unemployment rates of construction professionals have increased as a result of economic stagnation (Construction Industry Council [CIC], 2012). According to the Central Bank report (2012), the year 2009 was highlighted by the figures in key economic indicators. According to Perera and Waidyasekara (2013), recessional impact to the construction industry can be mainly categorised under six headings. They are financing, demand and supply, unemployment, constraint of material and plant, procurement and supply chain and future prospect led by customer confidence as illustrated in Figure 1. Criticalness of particular adverse effects were ranked according to the Relative Importance Index (RII) on each respective bar line.

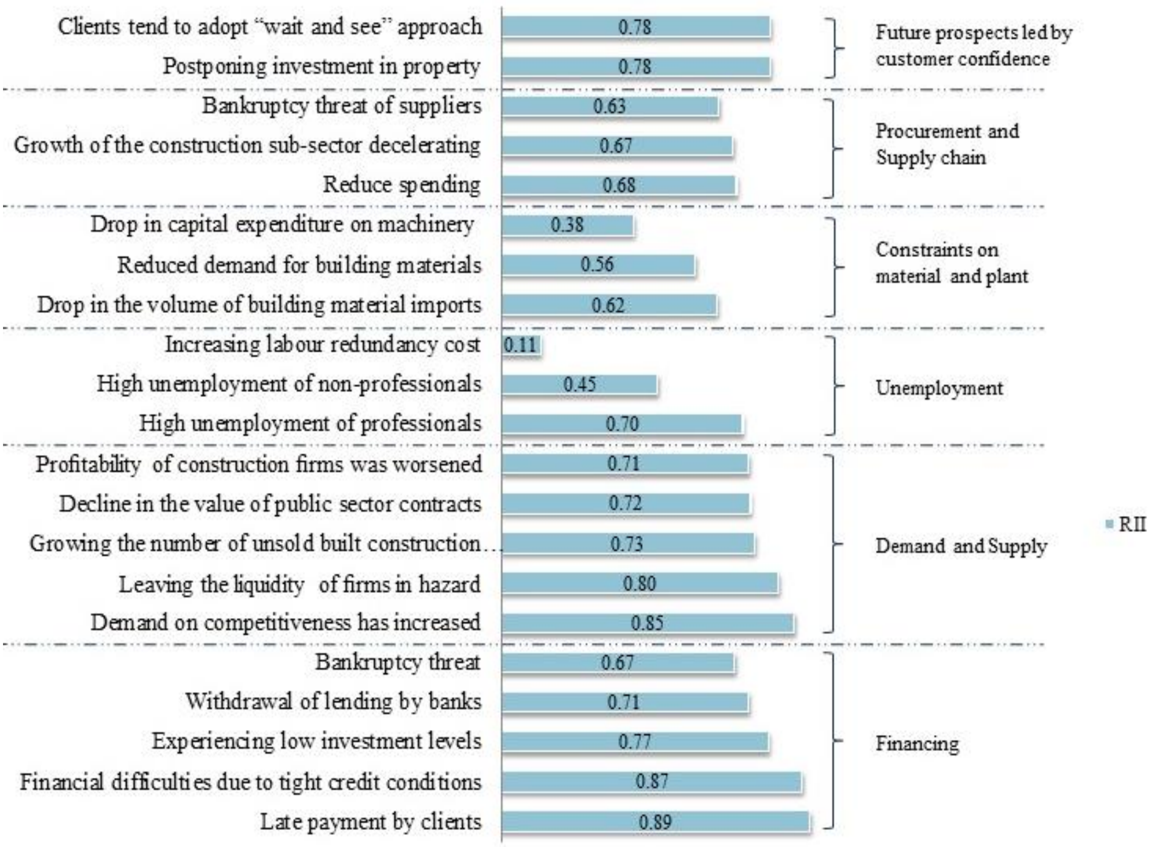

Figure 1: Adverse Effects on the Sri Lankan Construction Industry during the Economic Recession
Source: Perera and Waidyasekara (2013)

2.3. RECESSION RESPONSIVENESS IN THE CONSTRUCTION SECTOR

Recession responsiveness in the construction sector consisted of strategies that realise firms' objectives of continued existence and development in response to the recession (Lim *et al.*, 2010). Moreover, Kaklauskas *et al*. (2011) produced a crisis management model optimising all the macro variables to mitigate the effects of recession. Similarly, Kunc and Bhandari (2011) explored the strategy development process through the relationship between changes in performance measures and strategic success factors. Thus, recession responses have identified under three categories as Contracting-related, Cost-control related and Financial-related strategies (Lim *et al.*, 2010) as explained in Table 1.

Table 1: Recession Responsive Strategies

Contracting - related	Contractors adopt every possible way of procuring work to maintain their turnover (Lim *et al.*, 2010; Hillebrandt, Cannon and Lansley, 1995).
Cost control - related	A more active role in managing projects, company's cash flow and procurement procedures during the prolonged recession is highlighted under the cost control related actions (Lim *et al.*, 2010).
Financial-related	Managing the borrowing cost, capacity and the investment decision making are considered in financial related actions (Lim *et al.*, 2010; Hillebrandt *et al.*, 1995).

Tansey, Meng and Cleland (2013) have proposed a taxonomy, which utilises the well-known theoretical typology of Porter's (1985) generic strategies for responding to the economic recession. Porter (1985) has argued that a firm's strengths ultimately fall into one of two headings: Cost leadership and differentiation. By applying these competitive advantages in either a broad or narrow scope, three generic strategies are accomplished: cost leadership, differentiation, and focus (Porter, 1985). They are called generic strategies because they are not firm or industry dependent. Further, Tansey *et al.* (2013) determined that the differentiation strategies out of the three strategies were found to be the frequently used across the studies. The top four differentiation strategies adopted in the study of Tansey, *et al.* (2013) are as follows.

- Investing in R&D/new technologies
- Increase/improve marketing and advertising
- Improving relationships with stakeholders
- Improve/increase services/products offered

Similarly, Lim *et al.* (2010) described two classifications of Porter's generic theory (i.e. 'Differentiation' and 'Differentiation focus' strategies) are aligned with the aforementioned 'Contracting related strategies. Likewise, Porter's (1985) 'Cost Leadership' strategy is aligned with the 'Cost control related strategies which is to improve the firm's performance by cost cutting (Lim *et al.*, 2010).

2.4. BRIDGING RESPONSIVENESS: RECESSION TO SUSTAINABILITY

One of the key reasons for the current economic downturn is due to unsustainable business practices and inadequate focus on making a balance between monitory gains with social and environmental aspects (Kulatunga and Amaratunga, 2010; Chartered Institute of Building [CIOB], 2009). Further, increase of socially responsible investment is a key issue of incorporating greater demand side initiatives with supply side mechanisms which tends to boost up the economic activities (Pitt *et al.*, 2009).

Thus, the concept 'sustainability' could be defined as it meets the needs of the present without compromising the ability of future generations to meet their needs (Brundtland Commission, 1987). According to Kibert (2008), sustainability is a single indicator prescribing sets of multi-disciplinary indicators, which include three mutually reinforcing pillars as the ecological, social and economic issues. Policies and practice that support sustainable development have become more widespread concerns over the extent of man's activities on the natural environment. Hence, sustainable initiatives emerged as a solution to cure the adverse impact.

3. SUSTAINABLE RESPONSIVENESS

3.1. INTERPRETATION OF SUSTAINABLE RESPONSIVENESS

The authors offer definitions for 'sustainable responsiveness' as it is not yet established in the literature.

> "Sustainable responsiveness is a long term, proactive strategic solution to mitigate adverse effects in the construction industry during the prolonged recession. The responsiveness supports with the sustainable benefits which extend the responsibility of environmental integrity and social equity over economic development when selecting survival strategies for the long term healthy existence."

3.2. APPROPRIATE SUSTAINABLE RESPONSIVENESS

Contracting related strategies have contributed to the sustainable development during the recession. 'Minimising the cost of rework by quality output' to gain the value for money for the client was ranked at the top most contracting related strategies under the Sri Lankan construction context (Perera and Waidyasekara, 2013). At the same time reputation with clients plays important roles in dictating their ability to obtain sufficient jobs to tide over the recession (Green, Larsen and Kao, 2008). Furthermore, the need for diversification, scope for new opportunities, paradigm shift, appropriate pace creation and effective corporate governance may be considered as quick remedial measures to overcome from the economic recession (Jayaramana, Ibrahimb and Guatc, 2011).

Moreover, under the cost control related strategies, 'Implementing stricter site managed to reduce wastage' have attained the top most appropriate cost control related under the findings of Perera and Waidyasekara (2013) in the Sri Lankan context as well as under the classification of Lim *et al.* (2010) in the Singaporean construction context. Further, Cherif and Maira (2011) concerned internal and external collaborations and partnering with key suppliers in order to address the economic recession. Furthermore, restructuring of the workforce into teams, enabling share skills, resources and involving everyone in the economic struggle to survive and grow becomes a cost saving in a recession (Choppin, 1991). In other words, effective human resource management (HRM) differentiates from counterparts by maintaining a lean group of core staff. However, virgin HRM is not an attractive option in a recession.

Under the financing related strategies, Negotiating for alternative loan services', 'Security agreements with project owners and financial institutes', 'Investing into R&D to further explore business opportunities' and 'Investing surplus funds in financial investment' have been appropriate sustainable responsiveness (Perera and Waidyasekara, 2013). Furthermore, 'Reformulating firm's strategic objectives' and 'Practicing innovative procurement methods, like BOT model' are long term strategies during the recession. This change management is viewing the recession as an opportunity.

As per the opportunistic way of recession, the environment plays a major role in shaping firms' business strategies which screens the recession as a hostile environmental condition (Lane and Lubatkin, 1998). Thus, Kunc and Bhandari (2011) explored that firms may reformulate their strategic objectives to gain the merit in recession. This change management is viewing the recession as an opportunity which lead business either to sustain competitive advantage or to gain a completely new arrival (Rigby, 2001). Similarly, Lim *et al.* (2010) stated strategies towards sustainability. For an instance, Research and Development (R&D) is used to explore business opportunities during the worst time

3.3. COMPETITIVE ADVANTAGES OF ADOPTING SUSTAINABILITY

Many scholars have identified the benefits attributable in the concept 'sustainability' which is tabulated in Table 1 under the three mutually reinforcing pillars. Thus, the benefits of adopting sustainability in the internal environment can be reflected as 'strengths' according to the SWOT interpretation. According to Porter (1985), Competitive advantage grows out of value a firm is able to create for its buyers over the cost of creating it. Hence, Bansal (2001) stated the sustainable development prompts the opportunity to build stakeholder commitment and competitive advantage.

Table 2: Strengths of Sustainability

Economic benefits	Life cycle cost reduction	Sustainability leads to reduce the life cycle cost of the building (Richardson and Lynes, 2007). Thus, green buildings have reduced the life cycle cost by energy management, water management, and waste management (Bombugala and Atputharajah (2010)
	Increased performance	"Green" has become a shorthand term in the construction sector to denote high performance (LEED-EB Reference Guide, 2009). Further, operational efficiency in the sustainable built environment enhances the overall performance (British Standards Institution, 2003).
	Revenue generation	British Standards Institution (2003) described revenue generation through sustainable development. Furthermore, sustainability meant more profitability and competitiveness (DTER, 2000).
	True cost accounting	The construction sector is not only to deliver built facilities, further to look beyond exploring opportunities for long term sustainability align with social objectives rather than mere construction cost and short term profit (Purasinghe and Maguino, 2010).
Environmental benefits	Minimise demand on non-renewable resources	The aim of green construction is primarily to minimise demands on non-renewable resources and maximise resource utilisation. Thus, enhancing and protecting the natural environment (DETR, 2000).
	Minimise negative environmental impact	Sustainability eradicates adverse environmental impacts through high performance and energy saving ((LEED-EB Reference Guide, 2009). For instance, Ulagalla resort realised "Go Green" concept by 50% energy savings (Dissabandara and Peiris, 2010).
	Reduced legal compliance issues	Benefits of environmentalism to the construction industry which reduced environmental risk and improved relations with regulators. Consistently, the sustainability is a goal beyond the compliance (Sayce *et al.*, 2007).
	Favourable responses from pressure groups	However, despite the need for energy-efficient solutions, development interests and environmental activist groups have been adversarial in pursuing their respective agendas in favour of green construction (Carswell and Smith, 2009).
Social benefits	Enhanced reputation	Sustainable built environment promotes a higher corporate image and Corporate Social Responsibility towards the society resulted in sustaining the shareholder value (British Standards Institution, 2003).
	Consumer confidence	Sustainable construction provides greater satisfaction, well-being and value to customers and users (DETR, 2000). Thus, leads to Customer attraction and retention (Richardson and Lynes, 2007) by respecting and treating its stakeholders more fairly (DETR, 2000).
	Attracting and retaining staff	Lower energy costs and are perceived to be a healthier environment which supports staff retention by reducing absenteeism (Keeping and Shiers, 1996). In superlative, adopting sustainable development principles enhanced the human intellectual capital, productivity and well-being (British Standards Institution, 2003)
	Collaboration	Green constructions require collaborative effort, deep integration with every building aspect and require multi stakeholder involvement (Hwang and Tan, 2012; Shah, 2007).

Though, sustainable responsiveness is suggested to minimise the adverse effects of the recession in the construction industry, the assessment of the benefit of sustainable responsiveness is being the current gap. Thus, it needs to find out the relationship in between the strengths of sustainability and the adverse effects during the recession in order to illustrate whether or not the responsiveness are sustainably advantageous.

4. METHODOLOGY

An extensive literature review was carried out to investigate adverse effects in the construction industry during the recession, sustainable responsiveness and competitive advantages of sustainability. The study is then carried out through a survey approach to evaluate the extent of sustainability advantages (Strengths) to minimise adverse effects (Threats) in the construction sector during the recession. The expert survey was carried out among four different construction disciplines to gain multi-dimensional perspectives. They are construction consultants, construction contractors, economists and clients.

SWOT analysis could be used to analyse strengths, weaknesses, opportunities and threats of any given matter (Kaplan Financial Limited, 2010). The SWOT analysis matrix shown in Table 3 gives the idea of strategic direction consisted of four possible scenarios to gain the advantage of positive facts over negative facts such as, SO, ST, WO and WT (Kaplan Financial Limited, 2010).

Table 3: SWOT Analysis Matrix

	Strengths (S) +	**Weaknesses (W) -**
Opportunities (O)+	Use strengths to make use of opportunities (SO)	Take advantage of opportunities by overcoming weaknesses (WO)
Threats (T) -	Use strengths to overcome or minimise threats (ST)	Minimise the effect of weaknesses and minimise or overcome threats (WT)

Source: Kaplan Financial Limited (2010)

The basis of the data collection is in accordance with one quadrant, which is ST (Strengths - Threats) in the SWOT (Strengths, Weaknesses Opportunities and Threats) analysis as illustrated in the Table 3. The benefits inherent in sustainability under three pillars have been considered as ‘Strengths’ while the adverse effects in the external environment during the recession as illustrated in Figure 1 are considered as ‘Threats’ for the data collection process. The approach was more towards collecting qualitative ordinal data. Respondent’s self-assessment to determine the extent of sustainability strengths to minimise threats in the construction industry were measured according to the Likert scale given below.

Likert Scale: To What Extent Sustainability Strength Minimise Threats in Recession

1	2	3	4	5
Never	Rarely	Sometimes	Mostly	Always

Subsequently, Likert-type data analysis was based on the central tendency measurement, which is the median and the mode of the data set. The median is the middle value or the mean of the middle two values when the data set is arranged in ascending or descending order, which gives the central tendency. The mode is the value that appears the most, which gives the central tendency. It is possible to have more than one mode, and it is possible to have no mode (Weisberg, 1992).

5. DATA ANALYSIS AND RESEARCH FINDINGS

5.1. EXPLANATION OF THE MATRIX OF SUSTAINABILITY STRENGTHS – RECESSIONAL THREATS

Table 4 tabulates the broader illustration of the aforementioned SWOT analysis matrix. The matrix was developed based on the literature findings. The list of competitive advantages of adopting sustainability is shown in the rows of the matrix, categorising under economic, environmental and social benefits. Adverse effects in the construction industry during the recession are tabulated in the columns of the matrix, grouping under six main headings such as financing, demand and supply, unemployment, constraints on material and plant, procurement and supply chain and future prospects led by customer confidence. Each intersection of a column and a row is marked with the relationship, stating that, to what extent the particular sustainability strength minimise the particular adverse effect. The mode value of the responses is computed and illustrated in Table 4. Such value represents the respective digit and the meaning in the Likert scale. Thus, the relationship of two contrasting areas is built successfully.

Table 4: The Matrix Of Sustainability Strengths – Recessional Threats

STRENGTHS: Competitive advantage of adopting sustainable construction concept / THREATS: Adverse effects in the construction industry during the recession		Financing	Financial difficulties due to tight credit conditions	Bankruptcy threat	Late payment by clients	Withdrawal of lending by banks	Experiencing low investment levels	Demand and supply	Increasing the number of unsold apartments/blocks	Decline in the value of public sector contracts	Demand on competitiveness has increased	Profitability of construction firms was worsened	Leaving the liquidity of firms in hazard	Unemployment	High unemployment of non-professionals	High unemployment of professionals	Increasing labour cost	Constraints on material and plant	Reduced demand for building materials	Drop in the volume of building material imports	Drop in capital expenditure on machinery	Procurement and supply chain	Reduce spending	Bankruptcy threat of suppliers	Growth of the construction sub-sector decelerating	Future prospects led by customer confidence	Postponing investment in property	Clients tend to adopt "wait and see" approach
Economic benefits																											
Life cycle cost reduction	**Mode**		3	3	1	2	2		3	2	3	3	3		2	4	2		2	2	3		1	3	2		3	3
Increased performance	**Mode**		3	4	2	3	3		2	2	3	4	3		2	3	3		3	3	4		3	3	3		2	2
Revenue generation	**Mode**		4	4	2	3	3		3	3	3	3	3		3	3	3		3	3	3		4	4	4		3	3
True cost accounting	**Mode**		3	3	3	2	2		2	2	2	3	3		2	2	2		2	2	3		3	2	2		1	1
Environmental benefits																											
Minimize demand on nonrenewable resources	**Mode**		3	3	3	3	3		3	3	3	3	2		2	2	2		3	3	3		3	2	3		2	2
Minimize negative environmental impact	**Mode**		3	3	3	3	3		3	3	3	3	2		2	2	2		2	2	2		3	2	2		3	3
Reduced legal compliance issues	**Mode**		3	3	3	3	3		3	3	3	3	4		4	4	3		3	3	3		2	3	2		3	3
Favourable responses from pressure groups	**Mode**		3	3	3	3	3		3	3	3	3	3		3	3	3		3	3	3		3	3	3		3	3
Social benefits																											
Enhanced reputation	**Mode**		3	4	3	4	3		3	3	3	3	3		3	3	3		3	3	3		3	3	2		3	4
Consumer confidence	**Mode**		2	4	2	3	3		4	4	3	3	2		2	3	3		3	3	3		4	3	3		3	4
Attracting and retaining staff	**Mode**		2	3	2	2	2		2	2	3	3	3		4	4	3		3	3	3		2	3	3		3	3
Collaboration	**Mode**		3	3	2	2	2		2	2	2	3	3		3	2	2		2	2	2		2	3	2		3	2

5.2. *OVERVIEW OF THE RESULTS GENERATED BY THE MATRIX*

In the mere overview of the Table 4, the respondents have become neutral in the highest number of statements which is ‘Sometimes Minimise’. Further, there could not be seen any relationship of sustainability ‘always minimise’ adverse effect. Moreover, the respondents marked ‘Mostly Minimise’ in a lesser number of statements. Furthermore, there are a few sustainability advantages never minimises threats in the construction industry, leaving no relationship.

For instance the following statements appear to be two contrasting perspectives,

- ‘Life cycle cost reduction’ never minimises ‘Late payment by clients’.
- ‘Life cycle cost reduction’ never minimises ‘Reduced spending’.
- ‘True cost accounting’ never minimises ‘Postponing investment in property’
- ‘True cost accounting’ never minimises ‘Clients tend to adopt a wait and see mode’

5.3. *ECONOMIC BENEFITS*

Life cycle cost reduction, increased performance and revenue generation as competitive advantages of sustainability have contributed mostly in minimising the adverse effects as follows,

- ‘Life cycle cost reduction’ mostly minimise ‘High unemployment of professionals’
- ‘Increased performance’ mostly minimise ‘Bankruptcy threat’
- ‘Increased performance’ mostly minimise ‘Profitability of construction firms was worsened’
- ‘Increased performance’ mostly minimise ‘Drop in capital expenditure on machinery’
- ‘Revenue generation’ mostly minimise ‘Financial difficulties due to tight credit conditions’
- ‘Revenue generation’ mostly minimise ‘Bankruptcy threat’
- ‘Revenue generation’ mostly minimise ‘Reduce spending’
- ‘Revenue generation’ mostly minimise ‘Bankruptcy threat of suppliers’
- ‘Revenue generation’ mostly minimise ‘Growth of the construction sub-sector decelerating’

Revenue generation has the highest positive relationship in minimising adverse effects under the Economic benefits. However, true cost accounting as a sustainable benefit has given a lack of concern in minimising the adverse effects, dispersed in between the Likert rating of 1 and 3 (Never - Sometimes).

5.4. *ENVIRONMENTAL BENEFITS*

Reduced legal compliance issues as a competitive advantage of sustainability have contributed mostly in minimising the adverse effects as follows,

- ‘Reduced legal compliance issues’ mostly minimise ‘Leaving the liquidity of firms in hazard’
- ‘Reduced legal compliance issues’ mostly minimise ‘High unemployment of non-professionals’
- ‘Reduced legal compliance issues’ mostly minimise ‘High unemployment of professionals’

Many respondents come up with the same justification stating that, reduced compliance issues motivates the staff safeguarding their employment and further merited in terms of firms’ liquidity and profitability. Favourable responses from pressure groups as an environmental benefit resulted in sometimes minimising all the listed adverse effects. On the other hand, minimise demand on non-renewable resources and minimise negative environmental impact do not directly give positive relationship, which ranged in between 2 and 3 (Rarely - Sometimes).

5.5. *SOCIAL BENEFITS*

It must be emphasised that the social benefits contributed considerably for the threat minimisation. Enhanced reputation, Consumer confidence and Attracting and retaining staff as sustainability benefits have contributed in minimising the adverse effects as follows,

- ‘Enhanced reputation’ mostly minimise ‘Bankruptcy threat’
- ‘Enhanced reputation’ mostly minimise ‘Withdrawal of lending by banks’

- 'Enhanced reputation' mostly minimise 'Clients tend to adopt "wait and see" approach'
- 'Consumer confidence' mostly minimise 'Bankruptcy threat'
- 'Consumer confidence' mostly minimise 'Increasing the number of unsold apartments/blocks'
- 'Consumer confidence' mostly minimise 'Decline in the value of public sector contracts'
- 'Consumer confidence' mostly minimise 'Reduce spending'
- 'Consumer confidence' mostly minimise 'Clients tend to adopt "wait and see" approach'
- 'Attracting and retaining staff' mostly minimise 'High unemployment of non-professionals'
- 'Attracting and retaining staff' mostly minimise 'High unemployment of professionals'

Yet, social benefit 'collaboration' has not considerably resulted in a strong positive relationship for threat minimisation in which the mode values vary in between 2 and 3 ('Rarely'-'Sometimes').

5.6. DATA VALIDATION

The data analysis was based on the mode values of the responses. The results were then validated by the median values on the same platform of the central tendency. Therefore, according to Table 5, a very few cells have a deviation in between median and mode values. Since the variation is in between adjacent Likert ratings, it is negligible due to minor deviation. Thus, the results generated from the central tendency analysis confirmed its relationship between sustainability benefits and adverse effects.

Table 5: The Matrix of Sustainability Strengths – Recessional Threat

STRENGTHS: Competitive advantage of adopting sustainable construction concept / THREATS: Adverse effects in the construction industry during the recession		Financing	Financial difficulties due to tight credit conditions	Demand and supply	Increasing the number of unsold apartments/blocks	Leaving the liquidity of firms in hazard	Unemployment	High unemployment of non-professionals	High unemployment of professionals	Constraints on material and plant	Drop in capital expenditure on machinery	Procurement and supply chain	Reduce spending	Future prospects led by customer confidence	Postponing investment in property	Clients tend to adopt "wait and see" approach
Economic benefits																
Life cycle cost reduction	Median		2		2	3		2	3		3		2		3	3
	Mode		3		3	3		2	4		3		1		3	3
True cost accounting	Median		3		2	3		2	2		2		3		2	2
	Mode		3		2	3		2	2		3		3		1	1
Environmental benefits																
Reduced legal compliance issues	Median		3		3	3		3	3		3		2		3	3
	Mode		3		3	4		4	4		3		2		3	3
Social benefits																
Consumer confidence	Median		2		4	3		2	3		3		4		3	4
	Mode		2		4	2		2	3		3		4		3	4

Though some sustainability benefits do not directly result to the threat minimisation, gathered data expressed different derived relationships. Hence, the sustainability in the construction industry positively responds to the recession above the average (3) consideration which directs the forward movement even at an economy's stagnation. However, the respondents have agreed the need of public awareness to experience the sustainable benefits to minimise adverse effects of the recession.

6. CONCLUSIONS

The deterioration of macro-economic activities during the recession leads to a direct consequence in the construction activities. The literature review revealed that the weaken financial conditions due to late payment by clients and tight credit conditions have marked critical during the recession faced by Sri Lankan construction industry. Many of the contractors manifested their views of recession basically under the short term economic perspectives which can be considered as a reactive approach. Therefore, the need of an optimal extraordinary solution arises to mitigate the adverse effects in the construction sector. Hence, the sustainable responsiveness are introduced in the construction sector to focus on long term proactive strategic establishment.

Once the sustainable responses were figured out from different sources, the extent of sustainable benefits to minimise adverse threats during the recession was evaluated. In other words, a relationship was built between two contrasting perspectives. The respondents have become neutral in the highest number of statements which is 'Sustainable benefits sometimes minimise threats'. Consequently, the sum of Likert rating in the ascending order clinches the maximum at the Likert rating 3 (Sometimes minimise). Furthermore, it must be emphasised that the social benefits contributed for the threat minimisation mostly instead of the social benefit 'collaboration' has not considerably resulted in a strong positive relationship. In consideration to the economic benefits, mainly 'increased performance' and 'revenue generation' reasoned to mostly minimise recessional threats. While, reduced legal compliance issues as a competitive advantage of sustainability have contributed most in minimising the adverse effects.

Hence, the sustainability in the construction industry favourably responds the recession above average to mitigate threats and direct the forward movement even at an economy's stagnation by strategic establishment. However, the public awareness is essential to experience the sustainable benefits. However, the scope of this paper is limited to identify sustainability advantage to minimise threats in the recession. Hence, this paper gives the findings of an ongoing research process, which is then intended to categorise recession responsiveness by different construction stakeholders through an expert interview survey. Further, a framework will be developed to match the specific adverse effects with the suitable sustainable responsiveness to mitigate appalling effects of the recession.

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SUSTAINABLE STRUCTURAL MATERIAL COMBINING RECYCLED AGGREGATE AND STEEL FIBRES

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ABSTRACT

Recyclable concrete is now increasingly recognised as a sustainable building material, which could be effectively used in building construction. However, at present, recycled concrete created from recycled aggregate has mainly been used for non-structural and sub-grade applications around the world because companies have long believed that it is inferior to the normal aggregate generation. This research was undertaken with the hypothesis that recycled concrete can be as strong as the normal concrete which is suitable for structural applications when incorporated with steel fibres. Previous research has shown that steel fibre can effectively improve the toughness, shrinkage, and durability characteristics of concrete. Recycled concrete, which is weak in shrinkage properties, can therefore be enhanced by incorporating steel fibres. This paper reports initial experimental results that aims to explore the behaviour of recycled concrete when steel fibre is added. The experiments considered varying steel fibre volumes of about 0%, 30% and 60% with recycled aggregate replacement ratios of about 0%, 30% and 100%. It is found that the more recycled aggregate replacement ratio of the recycled concrete, the lower the compressive strength is. However, the addition of steel fibre can improve the compressive strength of the concrete mixes. The initial experiments reveal the possibility of creating a new material for structural purposes and will thereby contribute to sustainability by resolving environmental issues such as carbon emissions and wasted management. Future research will be carried out to conduct further tests when the material is used in structural members.

Keywords: *Australia; Recycled Aggregate; Recycled Aggregate Concrete; Shrinkage; Steel Fibre.*

1. INTRODUCTION

The global policy attention directed toward climate change and environmental sustainability has created challenges to the Australian construction industry (Manley and Rose, 2012). In particular the industry requires to seek innovative solutions for reducing the impact of constructing and maintaining the built environment on the earth. The structural frame of the building accounts for the highest cost of the building. Using environmentally and economically sustainable materials such as recycled concrete and steel fibres for the building construction would enable effectively respond to industry challenges.

Recycled concrete is now increasingly recognised as a sustainable building material. Recycled aggregate is wasted-crushed concrete consisting of old aggregate and old cement mortar. More than ten million tonnes of concrete waste were generated in South-Eastern Australia annually (Bakoss and Ravindrarajah, 1999; Australian Government: Productivity Commission, 2006; Queensland Government, 2007). Carbon emissions from the generated concrete waste have been considered as an important issue in Australia and around the world. The World Wide Fund for Nature reports that the concrete industry's share of global carbon emissions is about 8%. If recycled concrete is effectively used, the Australian construction industry may be capable of reducing its carbon emissions by up to 90% (World Wide Fund for Nature, 2010).

On the other hand, recycled concrete created from recycled aggregate has mainly been used for non-structural and sub-grade applications around the world because companies have long believed that it is inferior to the normal aggregate generation. Because of this misleading consensus, research on recycled concrete for high-grade structural applications and composite structures has been weak which has not realised its full potential. This project not only creates a new material for composite structural purposes but also resolves carbon emissions and wasted concrete storage problems (Commonwealth Scientific

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and Industrial Research Organisation, 1998; Commonwealth Scientific and Industrial Research Organisation, 2002; Commonwealth Scientific and Industrial Research Organisation, 2006).

Some researchers have compared the behaviour of composite steel-concrete beams using steel fibres and conventional reinforcement (Mookerjee *et al*., 1985; Mirza and Uy, 2009). These researchers have established that the composite steel-concrete beams with steel fibres could sustain higher loads than normal concrete. When steel fibre reinforcement was added to the concrete, the concrete exhibited improved confinement and better bond. Moreover, steel fibres also enhanced the rotational and moment capacity. The combination of steel fibres with a concrete slab not only increases structural stiffness and ductility, but also provides slabs with a fire rating ranging from 60 to 90 minutes (Mookerjee *et al*., 1985; Mirza and Uy, 2009).

Two aspects are to be considered when steel fibre reinforced concrete is used in concrete beams; shear stud resistance and ductility and the ability of steel fibre reinforced concrete to resist transverse shear in the slabs adjacent to the shear studs (Robery, 2002). Steel fibres have been replaced with welded wire fabric (WWF) as secondary reinforcement and verified that both deflection and cracks decreased in composite beams (Roberts-Wollmann *et al*., 2004). They also demonstrated that it was preferable to use steel fibres rather than synthetic fibres. A slab reinforced with 29.6 kg/m3 of steel fibres had a higher ultimate strength (18%) than a slab reinforced with WWF. Using steel fibres also resulted in a higher ultimate capacity. The researchers also showed that the composite beam reinforced with 0.9 kg/m3 of synthetic fibres failed at a load equivalent to the WWF (Roberts-Wollmann *et al*., 2004).

Generally, concrete which is weak in tension because of its low fracture strength is to resist predominantly compressive actions and the use of steel reinforcement is to resist predominantly tensile actions. Similarly, it is believed that recycled concrete with incorporation of steel fibres will offer a structurally sound material that is not only more cost effective, but also provide a reliable and sustainable solution to Australian Construction Industry. In line with this, this research will be expanded to include a reliability test and a cost benefit analysis.

In terms of reliability, the design codes in most countries including Australian Standards (OHBDC, 1983; ASHTO, 1994; Eurocode 3, 2002) have adopted the Load and Resistance Factor Design (LRFD) format (Faber and Sorensen, 2002). This format aims at achieving a relatively consistent reliability level in structural design through the appropriate introduction of safety margins. Under this format, the novel design should be used in structural design after careful verification of their mechanical strength prediction models and the associated safety margins (capacity factors), which should be determined based on a sufficient number of strength test results and rigorously measured uncertainties.

In terms of cost-benefits, although there is lack of cost information on this novel design, several previous studies showed the economic, environmental and social advantages of using recycled concrete against normal concrete. For example, it would reduce the need to use normal concrete and natural resources; avoid accidental collapses that would happen by unlimited use of sand and gravel from the river systems; reduce the need to treat construction and demolition waste before dumping; and save landfill spaces and life (Tam, 2008). On the other hand, use of steel fibre to strengthen concrete reinforcement structures is seen as a cost effective option that increase the durability and reliability of the structural design (Wang *et al*., 2000). The long-life span enabled by steel fibre would mean less operational costs. A proper cost-benefit analysis (CBA) would consider these benefits in evaluating feasibility of the new proposal.

All in all, this research is believed to be the first fundamental and comprehensive study of composite steel-concrete beams utilising recycled aggregate and steel fibres. It integrates the disciplines of civil, structural engineering and construction management, and employs computational techniques to gain a fundamental understanding composite steel-concrete beam utilising recycled aggregate and steel fibres. This investigation will improve the performance of composite beams while achieving sustainability and reliability. This paper examines the initial experimental results on the compressive strength of concrete cylinders with varied percentages of recycled aggregate and steel fibre.

2. EXPERIMENTAL STUDIES

Normal and recycled aggregate samples collected from south-eastern Australia centralised recycling plant were used for investigating the properties of recycled concrete. Table 1 summaries the water absorption and standards used for the normal and recycled aggregate samples.

Table 1: Water Absorption and Standards Used for the Normal and Recycled Aggregate Samples

Samples	Water Absorption (%)	Standards Used
10mm normal aggregate	1.2	(AS 1141.6.1, 1995)
10mm recycled aggregate	5.9	(AS 1141.6.1, 1995)
20mm normal aggregate	0.7	(AS 1141.6.1, 1995)
20mm recycled aggregate	4.3	(AS 1141.6.1, 1995)

A comprehensive set of experiments which considers a different steel fibre volume of about 0%, 3% and 6% with recycled aggregate replacement ratios of about 0%, 30% and 100% were examined. Details of all mix designs used for the recycled concrete experimental work are shown in Table 2. In total, nine mixes were conducted.

Table 2: Recycled Concrete Mix Designs Used for the Experimental Work

Mix	0-0	30-0	100-0	0-30	30-30	100-30	0-60	30-60	100-60
Cement (kg)	700	700	700	700	700	700	700	700	700
20mm normal aggregate (kg)	657	197	-	657	197	-	657	197	-
20mm recycled aggregate (kg)	-	460	657	-	460	657	-	460	657
10mm normal aggregate (kg)	329	99	-	329	99	-	329	99	-
10mm recycled aggregate (kg)	-	230	329	-	230	329	-	230	329
Coarse sand (kg)	310	310	310	310	310	310	310	310	310
Fine sand (kg)	100	100	100	100	100	100	100	100	100
Water (kg)	245	245	245	245	245	245	245	245	245
Superplastizer (litres)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Retarder (litres)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Steel fibre (kg)	0	0	0	11	11	11	21	21	21

The recycled concrete mixing was first charged with about half of coarse aggregate, then with fine aggregate, then with cement, and finally with the remaining coarse aggregate. Water was then immediately added after starting the operation for two minutes according to the Australian Standard (AS1012, 1993).

The 28-day compressive strength from the different mix designs for the recycled concrete were conducted based on Australian Standard (AS 1012.9, 1999). The average of the three samples of the 28-day compressive strength tests was calculated.

3. RESULTS AND DISCUSSIONS

This is the first time that composite steel-concrete beams utilising recycled aggregate and steel fibres are studied. Recycling of concrete waste as aggregate that is suitable for non-structural concrete applications is emerging as a commercially viable and technically feasible operation. The concrete industry at present globally consumes 8 to 12 billion tons of natural aggregate annually (Heeralal *et al*., 2009). This could cause large scale destruction of the environment. Utilisation of recycled aggregate can minimise the environmental impact and slowdown the huge consumption of natural resources used for concrete applications.

Researcher (Paskova and Meyer, 1994; Ong *et al*., 1997) had undertaken several studies on the effect of steel fibres on normal concrete but they did not consider the combination of composite steel-concrete utilising recycled aggregate and steel fibres. Common applications of reinforced concrete with steel fibres include paving applications such as in airports, highways, bridge decks and industrial floors (Spadea and Bencardino, 1997). By adding the steel fibres, it endures significant cyclic loading during their service life. This argument was not only agreed by the researchers (Subramaniam *et al*., 1999; Cachim *et al*., 2000), but they also proved that steel fibres distributed in the concrete delay the growth of cracks thus improve the ductility of the matrix. Therefore, implementing recycled concrete with steel fibres in the composite steel-concrete beams has a great potential.

The ability of steel fibres in improving the properties of concrete depends on the bond characteristics, aspect ratio of the fibres, surface friction and tensile strength of the fibres. Therefore, all of this will be undertaken in this research herein. Flexural failure is one of the principal modes of failure to be considered in the design of beams subjected to bending loading. The flexural criterion is the most important factor in the design of beam structures. The criterion is used to predict failure and is normally investigated through material testing and full scale beams test in laboratory.

3.1. MATERIAL STRENGTHS

Table 3 summaries the slump test results for the experimental work. It is ranged from 130mm to 240mm for the nine mixes. As the same amount of superplasteriser and retarder are added for each mix for controlling the consistent among the mixes, slight variations on slump test results are acceptable.

Table 3: Slump Test Results for the Experimental Work

Mix	Slump (mm)
0-0	220
30-0	190
100-0	160
0-30	220
30-30	200
100-30	150
0-60	240
30-60	130
100-60	170

Table 4 summaries the compressive strength test results for the experimental work. It is not surprised to find that the more recycled aggregate replacement ratio of the recycled concrete, the lower the compressive strength is. It relates to the attachment of old cement mortar on the recycled aggregate, which is the main source in reducing the concrete performance. For example, 43.40MPa is recorded for 0% recycled aggregate replacement ratio while 41.2MPa for 30% recycled aggregate replacement ratio and 35.77MPa for 100% recycled aggregate replacement ratio with no steel fibre added in the concrete mixes. Similar results can also found on 30% and 60% steel fibres added in the concrete mixes. With 30% steel fibre added in the concrete mixes, 52.17MPa is recorded for 0% recycled aggregate replacement ratio while 45.4MPa for 30% recycled aggregate replacement ratio and 35.50MPa for 100%

recycled aggregate replacement ratio. In addition, with 60% steel fibre added in the concrete mixes, 53.1MPa is recorded for 0% recycled aggregate replacement ratio while 46.1MPa for 30% recycled aggregate replacement ratio and 46.35MPa for 100% recycled aggregate replacement ratio.

Table 4: Compressive Strength Test Results for the Experimental Work

Mix	Compressive strength (MPa)				
	Test 1	**Test 2**	**Test 3**	**Average**	**Coefficient of Variation**
0-0	52.5	34.3	-	43.40	0.2965
30-0	40.5	40.6	42.5	41.20	0.0274
100-0	36.6	37.2	33.5	35.77	0.0555
0-30	47.0	47.8	61.7	52.17	0.1584
30-30	44.5	44.9	46.8	45.40	0.0271
100-30	42.1	32.2	32.2	35.50	0.1610
0-60	46.2	59.0	54.1	53.10	0.1216
30-60	44.2	40.3	53.8	46.10	0.1507
100-60	46.1	46.6	-	46.35	0.0076

The additions of steel fibre are aimed to improve the recycled concrete properties. From the experiment results, it is found that the addition of steel fibre can improve the compressive strength of the concrete mixes. With the additions of steel fibre, all concrete mixes with 60% volume of steel fibre found to improve the compressive strength results while the additions of 30% volume of steel fibre found to be slightly improve the compressive strength results with the same recycled aggregate replacement ratios. For example, 43.40MPa is recorded for 0% steel fibre volume while 52.17MPa for 30% steel fibre volume and 53.1MPa for 60% steel fibre volume with no recycled aggregate added in the concrete mixes. Similar results can also found on 30% and 100% recycled aggregate replacement ratios in the concrete mixes. With the 30% recycled aggregate replacement ratio, 41.2MPa is recorded for 0% steel fibre volume while 45.4MPa for 30% steel fibre volume and 46.1MPa for 60% steel fibre volume. With the 100% recycled aggregate replacement ratio, 35.77MPa is recorded for 0% steel fibre volume while 35.5MPa for 30% steel fibre volume and 46.35MPa for 100% steel fibre volume.

It should be highlighted that the additions of 60% steel fibre volume for the recycled concrete mix can improve the compressive strength of recycled concrete. Further research is required to investigate whether further additions of steel fibre volume can further improve the performance of recycled concrete.

3.2. *STATISTICAL ESTIMATION OF DESIGN STRENGTH*

To confirm the structural use of the proposed composite steel-concrete beams with recycled aggregate and steel fibres, the design strengths of the proposed composites are calculated and compared based on the reported initial test results, as a preliminary study. The design strength of a material is defined by the characteristic strength divided by a partial factor and is calculated using the following equation (AS 5104, 2005):

$$f_{cd} = f_{cm} \exp(-\mathrm{k_d} \mathrm{V}_{f'_c} - 0.5 \mathrm{V}^2_{f'_c}) \qquad \text{(Eq: 01)}$$

where f_{cd} = design compressive strength of concrete, f_{cm} = mean measured compressive strength of concrete; $\mathrm{k_d}$ = the fractile factor corresponding to the target reliability index β considering the uncertainties from a number of test data N using a t-distribution; and $V_{f'_c}$ = the coefficient of variation of the characteristic compressive strength f'_c.

Here, the target reliability index is taken as 3.04, by multiplying the target reliability $\beta_t = 3.8$ suggested for ultimate limit-state design and the First Order Reliability Method (FORM) sensitivity factor when resistance is taken as 0.8 (EN 1990, 2002).

Using Eq: 01, the design strength of the three representative mix cases are calculated: (i) no recycled aggregate replacement and no steel fibre, (ii) 30% recycled aggregate replacement and no steel fibre, and (iii) 30% recycled aggregate replacement and 60% steel fibres. The design strength of case (i) is calculated based on = 0.10 (AS 3600, 2009), and no uncertainty due to an insufficient number of data is considered because its design strength has already been confirmed by many test results. However, the design strengths of cases (ii) and (iii) are calculated based only on the reported test results because there are no further test results. In these cases, is taken as 0.11, which is estimated by averaging the coefficient of variations for all mix cases, based on the assumption that the coefficient of variation is constant for varying mean measured strengths. The coefficient of variations for each mix case is calculated in Table 4, and the calculation results of the design strengths are reported in Table 5.

Table 5: Design Strengths

Mix	Design Strengths (MPa)
0-0	31.86
30-0	28.05
30-60	31.39

From these calculation results, it should firstly be noted that the mix design with 30% recycled aggregate replacement with no steel fibres shows slightly lower design strength than that of the normal concrete. This is due to the slightly lower mean measured compressive strength and the uncertainty created from the insufficient number of data collected. The result can be improved by collecting more experimental data, but based on the reported initial test results, the 30% recycled aggregate replacement cannot replace normal concrete in structural design. Second, it should also be noted that the strength reduction by the use of 30% recycled aggregate replacement can be overcome by adding 60% steel fibres as shown in Table 5 where the design strength of cases (i) and (iii) are very close to each other. This indicates that mix case (iii) can be used in a real design to replace normal concrete even based on the current limited number of test results. As more experimental data are collected, the design strengths may increase as the uncertainties from the insufficient number of data are reduced.

3.3 COST-BENEFIT ANALYSIS

It is not only important to analyse the structural suitability and reliability of the novel design, but also the cost effectiveness. The novel design may not be attracted if it is not financially feasible. By carrying out a CBA, this research aims not only to evaluate the immediate economic benefits of the novel design, but also identify the environmental and social benefits to prove the sustainability effects of the design. CBA had gained popularity in evaluating feasibility of new designs that carry significant environmental advantages.

Cost effectiveness of using recycled concrete as a material over normal concrete has been proved by using CBA (Tam, 2008). However, there are no studies that had looked into the cost effectiveness of a structural member when utilising sustainable material such as recycled concrete with steel fibre. Altun and Aktas (2013) explained that steel fibre can be mixed together with concrete for partial or full replacement of traditional steel work decreasing labour intensive hours, delivery, storage and the need for continuous inspections thus saving time and money. Full replacement of traditional steel also decreases cost on steel reinforcement which is one of the most expensive component in structural elements. Therefore, by adding steel fibre (60% -21kg) to recycled aggregate concrete which is very less expensive to reinforcement (generally $3 per kilogram), there will not be a significant cost increase even in the initial costs. When the economic benefits of RAA are considered along the lifecycle costs significant benefits are predicted for this option. Hence, a CBA is underway for this study by comparing the two options (1) Composite beams with normal concrete, and (2) Composite beams with optimal combination of recycled concrete and steel fibre (30-60). Cost data will be gathered from published resources and in-depth interviews with industry practitioners. The following steps will be considered in the analysis.

- Step 1 is to quantify and estimate all initial (direct and indirect) costs, such as material, labour, equipment, transportation and overhead costs or benefits.
- Step 2 is to decide appropriate discount rates, and identify operating costs such as maintenance and repair costs.
- Step 3 is to identify environmental costs and benefits such as savings on construction waste (waste treatment charges; dumping charges, landfill space costs, transportation costs, air pollution costs, gas emission costs, energy consumption costs, noise pollution costs); and, savings on use of natural resources.
- Step 4 is to identify social costs and benefits such as reduction of accidental collapses with unlimited use of sand and gravel from river systems and threat to lives.
- Step 5 is to find the best option in terms of cost effectiveness will be identified based on economic costs (initial and operating as identified in Steps 1 and 2) and the identified environmental and social costs and benefits (as identified in Steps 3 and 4).

It is expected the results will show the significant economic benefits when the costs across a life span are considered for recycled option against the normal concrete option.

4. CONCLUSIONS

This paper examined the initial experimental results on the compressive strength of concrete cylinders with varied percentages of recycled aggregate and steel fibre. The experiments considered varying steel fibre volumes of about 0%, 30% and 60% with recycled aggregate replacement ratios of about 0%, 30% and 100%. It is found that the more recycled aggregate replacement ratio of the recycled concrete, the lower the compressive strength is. However, the addition of steel fibre can improve the compressive strength of the concrete mixes. This should be highlighted that the additions of 60% steel fibre volume for the recycled concrete mix can improve the recycled concrete compressive strength. In addition, a statistical analysis was carried out to estimate the design strengths of the proposed mix cases. Although a small number of test results are considered, the calculation results showed that, by adding 60% steel fibres to recycled concrete with 30% recycled aggregate replacement, the design strength of the recycled concrete becomes similar to that of normal concrete and can therefore be used in structural design. Further research is required to investigate whether further additions of steel fibre volume can further improve the performance of recycled concrete. On the whole, this research will bring significant benefits to the industry by effectively using waste materials and forming a closed system for concrete.

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URBAN DESIGN AND SOCIAL CAPITAL: LESSONS FROM A CASE STUDY IN BRAUNSTONE, LEICESTER, UNITED KINGDOM

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ABSTRACT

A valuable asset in sustainable regeneration is the 'community' in an area with their developed networks, bonds and ties or in other words its social capital. Braunstone in Leicester is typical of many disadvantaged areas in the UK, with persistent socio-economic problems exacerbated by a poor physical setting. With a large regeneration programme funded by the New Deal for Communities coming to a close, we conducted a case study to explore the impact of improved local facilities and the effect of walkability on social capital.

The lessons learnt suggest that responding to needs at a finer grain is vital in developing neighbourhoods for social capital. Such fine grain responses should include the needs of different user groups, local patterns of use and measures to improve the branded and stigmatised perceptions of neighbourhoods. Accessing services by walking and using public transport is vital to engage in social activities, while a poor physical environment and a lack of accessible services affects levels of participation. Local facilities provide a mediating role in developing social capital in a community by providing opportunity for social interaction that encourages people to reside in an area in the longer term. Integration of the neighbourhood in its wider context with easy connections to the outside world is a vital incentive for longer-term residency if social capital is to grow over a period of time.

Keywords: *Braunstone; Community Development; Regeneration; Social Capital; Urban Design; Walkability.*

1. INTRODUCTION

Social capital of a community is a valuable asset in regeneration projects. Human capital is the attributes of individuals defined by one's skills, qualifications and knowledge, while social capital refers to an asset generated by being part of a 'community'. The World Bank defines social capital as "the institutions, relationships, and norms that shape the quality and quantity of a society's social interactions. Social capital is not just the sum of the institutions which underpin a society – it is the glue that holds them together (World Bank http://go.worldbank.org/K4LUMW43B0, 2004)". Social capital is an intangible asset that develops over time with the goodwill, bonds or trust that result from shared values, outlook on life, attitudes or behaviours that can become a resource to serve common goals. As this concept deals with aspects of social structure that enable social action, it can be a resource in sustainable urban regeneration to achieve common goals such as higher educational attainment, better health, lower levels of crime, more effective forms of government and growth in GDP (Harper, 2001; Aldridge *et al.*, 2002).

The physical design of neighbourhoods can impact on social capital of communities. The contribution of the environment appears as a variable in research on social capital and public health (Macintyre and Ellaway, 1998; Kawachi *et a.l*, 1999a; Baum and Palmer, 2002) and also in social capital and crime (Kawachi *et al*., 1999b, Lindstrom *et al*., 2003). The manifested nature of social capital in a neighbourhood is context specific and is determined by history and culture, social structures, economic inequalities and individual consumption patterns (Cladrige, 2009). There is lack of operational knowledge on this theoretical construct including any in–depth discussion of the role of physical design

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in relation to social capital. However, there is renewed interest in recent regeneration initiatives to improve the quality of the environment to promote healthy and active life-styles and social equality. This operational knowledge gap if bridged can provide an impetus for sustainable regeneration.

The SUE–MOT (Sustainable Urban Environment: Metrics, models and Toolkits, Engineering and Physical Sciences Research Council grant no. GR/S18311/01) project aimed to encourage key decision-makers to systematically assess the sustainability of urban development by facilitating decision-making at every stage of the development process. In the 'social capital work package' we identified urban design attributes that encourages the growth of social capital in sustainable urban development. This paper reports the lessons learnt from a case study in Braunstone, Leicester that explored this relationship to gather operational knowledge**.**

The New Deal for Communities (NDC) regeneration programme provided resources to tackle five key themes in the most deprived areas in the UK: poor job prospects, crime, educational under achievement, poor health, and problems with housing and the physical environment. In Braunstone Leicester, a £49.5 million community led regeneration scheme - 'A New Deal for Braunstone (BNDC)' was implemented in 2002 to 2009 in order to improve the area and to develop the community. There was substantial investment in buildings to provide a library, civic centre, health centre and leisure facilities aiming to improve the quality of life. BNDC comprises nearly 5000 properties with a population size of 15,000 - around 74 per cent of the residential properties are owned by Leicester City Council.

We conducted a case study to explore the impact of improved facilities, buildings and the effect of walkability on social capital in the area. We sought to find answers to two main questions through the case study;

- Has social capital in the Braunstone community been affected by the building of new facilities such as the Brite Centre (learning centre) and Braunstone Leisure Centre (sports facilities)?
- Does the walkability of the neighbourhoods affect the social capital of the area?

As the 'softer' and 'intangible' attributes dealt with cannot be easily quantified, the study specifically looked at proxies that could be made use of in the assessment of 'walkability' and improvement to facilities that helps build social capital.

2. METHODOLOGY

The hypotheses for this study was derived from our earlier work which established key attributes of urban design that contributes to social capital. Historical evidence and relevant literature were reviewed to get an insight into the socio-economic and physical context of the study area. We gathered hard and soft data on key demographic characteristics, walking environment, use of leisure facilities and social capital. A questionnaire survey captured information from one hundred and thirty nine responses from residents living inside and outside the 'Braunstone New Deal for Communities' area. The information was gathered as a rank order of preference and as a selection of choices. The data gathered were on the

- Use of the facilities and their physical features and perceptions of local residents on these facilities
- The walking environment, socio-economic background, frequency of places visited for social interaction and participation in social activities
- Trust and sense of belonging within the community.

Following this, two workshops were conducted with two small groups of ten local residents across a range of ages to gather qualitative data on local issues raised in the questionnaire survey, such as the use and perception of the facilities, nature and places for social interaction and key issues on walkability of the area.

A site survey of the walking environment supplemented the data collected from the questionnaire survey. Records of activities in a typical day in the Brite Centre and Braunstone Leisure Centre noted the time and type of activity. Qualitative observations were also recorded regarding the nature of users, what they did at the centres, when and with whom. This was supplemented by 'user data' of the Braunstone Leisure Centre provided by the Leicester City Council.

Spatial data, such as land-use patterns, street connectivity, bus-stops, public transport routes and location of the key services (used for social interactions) were collected from secondary sources. The relative street connectivity of the neighbourhoods was analysed considering the density of cul-de-sac streets within each neighbourhood. A proximity analysis was conducted using Geographical Information System (GIS) to assess the accessibility to the key services of the neighbourhoods by walking (within 10 minutes walking distance) and public transport.

3. URBAN DESIGN AND SOCIAL CAPITAL

If intangible assets such as goodwill, bond and trust arise from shared commonalities, can the urban design of neighbourhoods support and promote opportunity for such shared commonalities to develop? Acknowledging the 'facilitator role' of the physical environment, Carmona *et al*. (2003) argued that urban designers influence, inhibit, facilitate, and modify, but do not determine patterns of human activity and social life. Gehl (1971) suggests that the physical framework does not have a direct influence on the quality, content and intensity of social contacts. The environment can affect possibilities for meeting, seeing and hearing people acting as a background and starting point for many forms of contact to develop.

We explored the intersection of social capital theory, urban design guidance and empirical research on social capital that considers the built environment as a variable. Our work revealed twelve recurrent attributes that help people to live, work and relax and thus encourage formal or informal interaction and longer-term residency in the area in which they live, aiding the growth of social capital (refer Figure1). The urban design guidance (UDG) reviewed were from a range of organisations in the UK that publish such guidance, namely: government organisations such as the Department for Environment, Transport and The Regions (DETR), the Department for Transport (DfT), the Office of the Deputy Prime Minister (ODPM) and the Association of Chief Police Officers (ACPO); affiliated government bodies such as the Commission for Architecture and the Built Environment (CABE) and English Partnerships; and third sector organisations such as the Prince's Foundation for the Built Environment and the Joseph Rowntree Foundation (JRF). The principles of urban design set out in these documents have been extracted from the shared experience of practitioners, on the premise that places can be developed in a way that enables people and communities to achieve their full potential for a higher quality of life.

The key concepts through which urban design can facilitate and allow for social capital to evolve are to design for retaining people in the area for the longer term and to provide for means of repetitive interaction. Extrapolating urban design guidance above together with published research, four themes and twelve attributes that facilitate these two key concepts were identified, thus allowing social capital to evolve (Paranagamage *et al*., 2010).

3.1. THEME 1 - CONNECTIVITY

Attribute 1 - Movement structure: Walkable neighbourhoods contribute to the presence of people on the streets that fosters a sense of community. Lund (2002) argued that the sense of community was greater in pedestrian oriented neighbourhoods compared to automobile oriented places. Dependence on the automobile corresponds with reducing levels of social participation. People living in 'walkable' neighbourhoods knew their neighbours better and trusted them and were more socially engaged (Leyden, 2003).

Attribute 2 - Mixed use: A variety of retail, commercial and community facilities accessible within a walk of five to ten minutes encourages people to use them. Major employment centres, secondary schools and public facilities such as large hospitals if easily accessible through public transport also contribute to the longer term success of neighbourhoods. Mixed-use streets facilitate social inclusion by attracting a wider population of age and ethnicity and also offer employment opportunity. They encourage social exchange and contribute to reduce feelings of isolation and depression by creating a 'hub' with strong sense of local identity in their community (Jones *et al*., 2007).

Attribute 3 - Local facilities: A good range of local facilities, services and amenities with ease of access provide opportunity to be involved in one's community. They facilitate collective action, allows ties and a sense of trust to develop. Meeting places such as pubs, corner shops or sporting grounds create opportunities to maintain loose ties and networks.

3.2. THEME 2 - SAFETY

The absence of 'social buffers' such as formal and informal networks is correlated to high incidence of crime in urban areas. There are fewer muggings, assaults and burglaries in communities with tight bonds and active participation (Lindstrom *et al.,* 2003). Perceptions of safety are associated with trust in neighbours. The sense of reciprocity is associated to bonding capitals (Baum and Palmer, 2002) that result in feelings of belonging within the neighbourhood.

Attribute 4 - Ownership: Places designed with sensitivity to the needs of the users with good integration between buildings and external spaces, encourage social interaction and helps to create a sense of place. Well used places with a sense of ownership provide fewer opportunities for crime.

Attribute 5 - Natural surveillance: Design can have a role in creating a sense of safety and security. Streets which are well overlooked and active throughout the day and evening benefit from the presence and surveillance of residents and visitors.

Attribute 6 - Access and footpaths: Paths should lead people directly to where they want to go by foot, cycle or public transport. To ensure the presence of others, pedestrians, cyclists and vehicles should run alongside with good visibility. Clear signage, landscaping and points of interest such as market stalls, places to sit and street art maintains the interest of users.

3.3. THEME 3 - CHARACTER

Attribute 7 - Context: Sensitivity to context makes one place different from another which people can appreciate easily. Those who identified themselves with the neighbourhood as a unit which is larger than the individual home but smaller than the district, were more likely to have bonding capital, suggesting that a sense of scale adds to a sense of belonging (Altschuler *et al*., 2004).

Attribute 8 - Public space: Character of public space will vary as 'go to places' or destinations for staying, eating, meeting or events, 'go through' or as spaces to pass, such as favoured streets or squares, or 'stop in' places, to sit and watch the world go by; or indeed a combination of all these. Such places are a resource for both individuals and communities for social interaction to sustain a sense of community and to provide opportunities for bonding, making ties and bridges that promote 'well-being'.

Attribute 9 - Personalisation: Correct levels of privacy enable people to feel at ease within their home. Provision to fix their personal stamp on a dwelling and surroundings also contribute to the sense of identity. The limited range of visible attributes may manifest the shared values for a neighbourhood according to unwritten rules. Norms and shared values are also within latent conformities that underlie the manifested components in the design of domestic space such as in 'Space codes' (Hanson, 1998) that may need to be recognised.

3.4. THEME 4 - DIVERSITY

Attribute 10 - Life cycle needs: Successful places have the adaptability to changing circumstances and are inclusive to diverse needs of people allowing for changing needs across the lifecycle. For example, the attachment to a place in older age constructed by long residency helps develop trusting and reciprocal relationships with neighbours.

Attribute 11 - Mixed tenure: Sustainable urbanism should promote social integration and mitigate the stigma associated with social housing providing a choice of tenures with a range of housing sizes and types. There is decreasing levels and class specific participation that suggests a decline in social capital in the UK. If differences may not allow for bonding, neighbourhoods could help increase social inclusion by providing a mix of housing types for degrees of affordability contributing to bridging social capital. Shared streets used by different tenure groups such as social and private tenants and owner occupiers, increases the chances of spontaneous interaction, thus help build social capital.

Attribute 12 - Life style differences: Exclusion by design is more likely to be felt by marginalised groups such as disabled, older people, minority faiths, and carers with young children or women. If neighbourhoods accommodate different densities accommodating housing for couples, singles and families, the differences in lifestyles between the groups would demand a variety of services and facilities to sustain them.

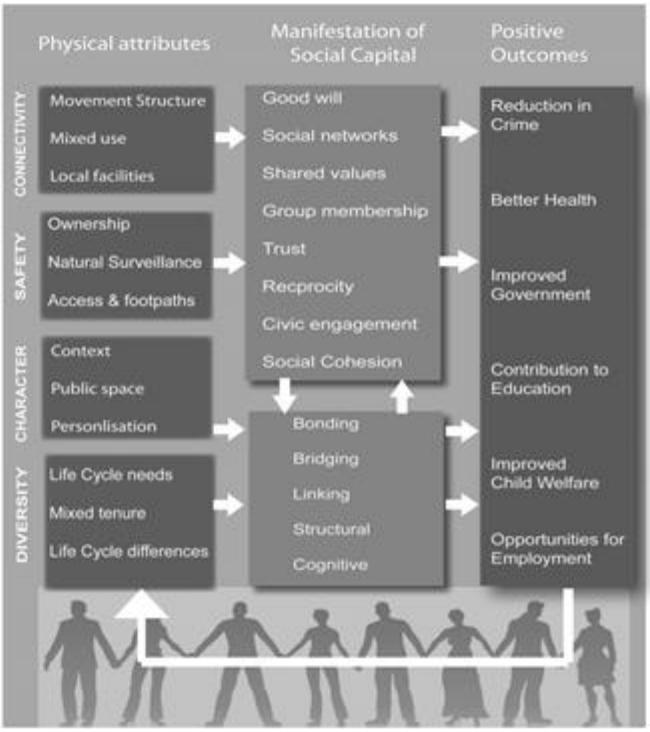

Figure 1: Physical Attributes Contributing to Social Capital

4. KEY FINDINGS

It is clear from our previous work described in the preceding section, that the built environment plays a mediating role for social capital to develop. Therefore it was unwise to directly measure a relationship between social capital and attributes of urban design in the Braunstone case study. We used proxies such as the use of local facilities and degree of walkability, which indicated the level of opportunity the built environment, can provide to foster this asset.

Overall, the findings suggest that Braunstone is typical of many disadvantaged areas, with persistent socio-economic problems exacerbated by a poor physical setting. Local facilities and neighbourhood walkablity provides incentives for longer term residency, and facilitates social interaction helping social capital to evolve and grow. Accessing services by walking and public transport proves vital to perform the day-to-day life and social activities; on the contrary, a poor physical environment, lack of accessible services and public transport affect levels of participation in social and leisure activities thereby limiting opportunities for social interactions. This in turn can reinforce health inequalities and social isolation of the most disadvantaged groups from the wider communities (Marmot, 2010).

However, findings suggest that responding to needs at a finer grain, rather than that of the larger neighbourhood as a whole, is a vital requirement in developing neighbourhoods for social capital. The findings are not mutually exclusive but relate to each other closely.

4.1. SOCIAL CAPITAL IN BRAUNSTONE

The strong sense of community prevalent in Braunstone indicated high levels of social capital. The importance of socialising was higlighted, comparing well with the results from 2008 MORI survey data (Boeck and Lea, 2009) with high percentages stating that people in the community were friendly. There were good levels of trust with feelings of being part of the community and a significant number giving unpaid help in the community (refer Figure 2).

Longer term residency in the area is an important proxy as social capital evolves over time with increasing reminiscence and face-to-face interaction. Respondents reiterated the importance of such interaction through the opportunity to meet as "I lived in the same house for 42 years in Braunstone; I was 21 when I came here; A lot of people in the area used to work for firms; Every firm had their own social activities; own big swimming pool; dancing activities and Quakers activities; night time dinners; have a shower and go out to the netball clubs, absolutely fantastic."

Many residents were either satisfied or fairly satisfied with their accommodation, and did not have an intention of moving. Nearly half of those who intended to move in the next two years wanted to be within 15 minutes walking distance to their current home or move within a neighbouring area, showing strong connections to the area. More than two thirds indicated a satisfaction with the area, standards of living, surroundings and friendships, which is comparable to the national average. This is a strong positive indicator for the intention of longer term residency.

The over 65s age group had comparatively a high level of social capital compared to the younger ages. Couples without children and families with children also reported higher levels of social capital. As such, local connections and networks may be more important for people with particular lifestyles and in specific stages of their life. Social capital may increase with longer term residency as those who had lived in the area for more than 10 years had the highest level with levels increasing with the length of residency.

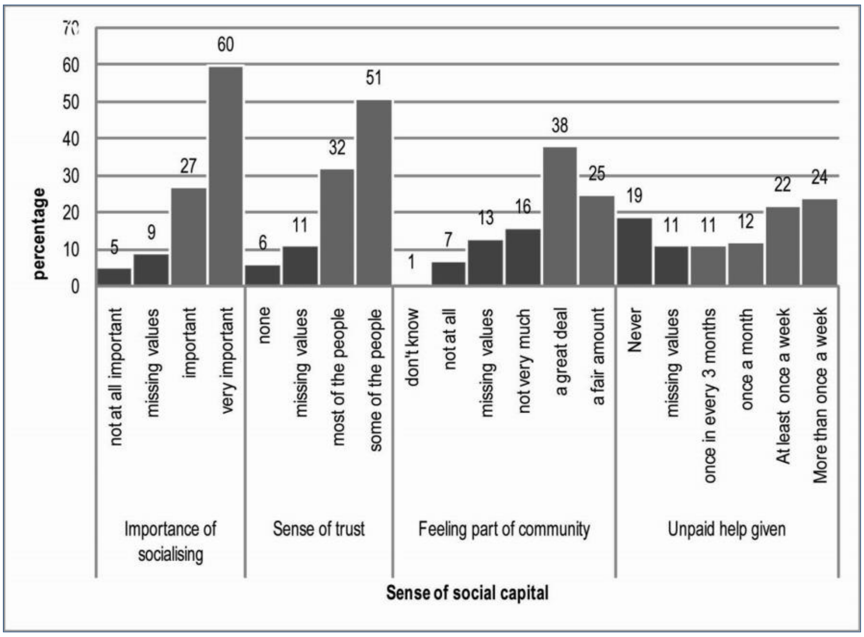

Figure 2: Social Capital Measurements in Braunstone

4.2. RESPONDING TO NEEDS OF DIFFERENT GROUPS

The design of neighbourhoods such as Braunstone should be fine-tuned to the needs of smaller groups if a growth of social capital is to be expected. Because patterns of socialising vary at a fine grain, the physical design of facilities and neighbourhoods needs to cater for this variation. The message was clear as said by an older respondent, "we need more activities in the Braunstone park where older people could watch the younger generation in their activities", suggesting a level of intervention that considers an inclusive approach sensitive to needs. To another respondent, "Braunstone had certainly improved; People are a lot friendlier; I lived in sheltered housing in Braunstone for two years; I have been meeting people in Braunstone and they are lovely; Facilities for older people are a little bit…mm" suggesting that opportunities for migrants to interact with the community would be important to develop bonds and bridges.

As required by the demographic profile, local facilities need to be responsive to the emergent needs of groups if a growth of social capital is to be encouraged through better use of facilities. For example, the elderly liked to socialise rather than engage in physical activity, youth did not use the facilities for

Socialising while those with low incomes found that, activities did not cater for their needs. Families with children had expressed concerns of anti-social behaviour which prevented them from using the facilities more (refer Figure 3).

For those inclined to walk, such as those without cars, the perceived safety of the environment was a clear incentive, whereas for others, such as those with cars, comfort and convenience were important. A poor quality environment and lack of access to services affects walking behaviour, negatively affecting social interactions of those with low income. As such, a detailed understanding of expectations needs to be taken into account when deciding the priorities.

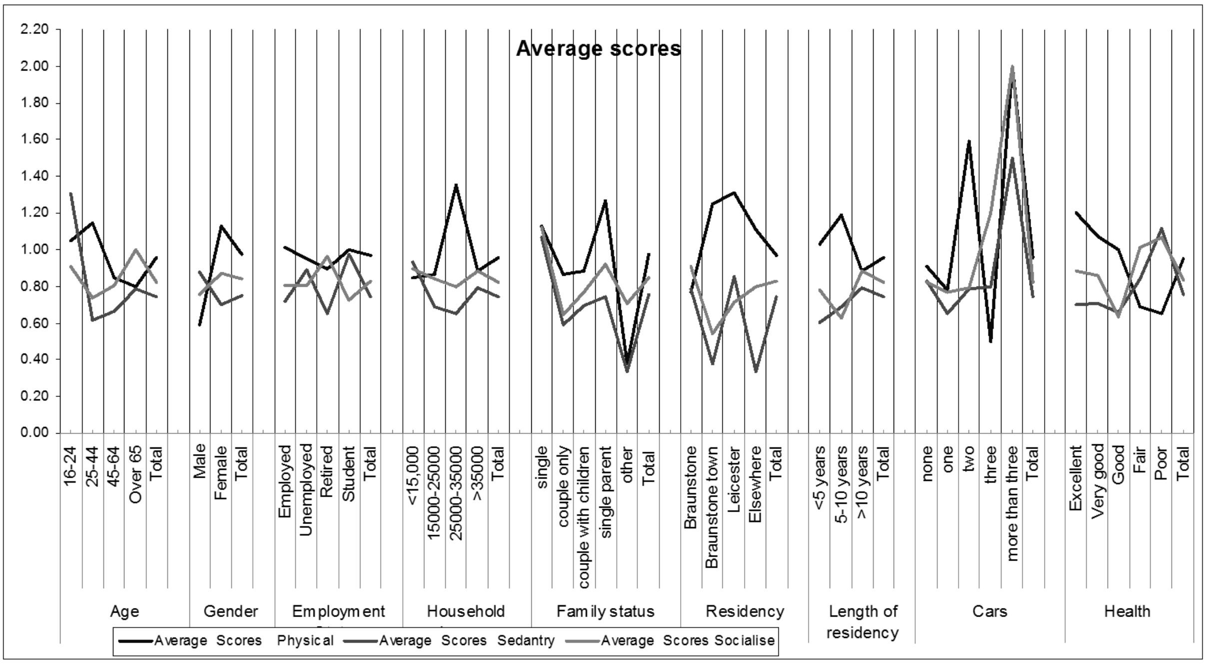

Figure 3: Levels of Social Capital in Groups Split by Nature of Activity

4.3. *RESPONDING TO LOCAL PATTERNS OF USE*

Braunstone and non-Braunstone residents used the local facilities for different purposes. For locals, especially, longer term residents, they were mainly social hubs to meet friends and family as well as for skills enhancement. Spaces which allowed for socialising, for example waiting areas were used for casual connections such as a quick chat among those who were attending classes or waiting to pick up children from a crèche. The library had a range of spaces creating opportunity for interaction such as places for coffee mornings, with adjacent spaces of relative isolation for quiet study. In comparison, the Braunstone Leisure Centre offers potential for short casual connections encouraging weaker bonds among the diverse range of people that use it, which plays an important role in social capital. The arrangement and positioning of spaces in facilities can add to the ambience needed for the different forms of bonding, bridging and networking which take place. In places such as Braunstone where strong bonding capital exists, local facilities and services can play a significant role in fostering better health. Social capital can also influence behaviour and choices to adopt a healthy life-style with such social exchange contributing to improve wellbeing and also provide informal support and care.

For non-residents of Braunstone, the facilities were places for physical leisure activity in addition to skill enhancements. The participation of outsiders within the community could contribute positively to counteract the stigma and isolation from Leicester City that Braunstone suffers from, and promote the area as an inclusive place. Encouraging bridging and linking social capital is important for Braunstone if the vision to change from the current mono- tenure social housing to a more mixed tenure estate is to be promoted.

4.4. *RESPONDING TO NEEDS OF LOCALITIES*

The Braunstone Park divides the area into two distinct parts: the North and the South. Poor connectivity and limited pedestrian routes across the park had deterred walking between these two neighbourhoods. Braunstone is known to have previously suffered from lack of services with closures of existing services worsening the situation (Hickman *et al*., 2008). Accessing services within the local and surrounding areas by public transport was also seen as a problem. As said by a respondent "The access is the problem. If not for the bus I won't be able to go there. There is a lot that goes on there but I don't go to the Braunstone Leisure Centre; I went there for swimming but that did not work out; they needed a big one in the centre for all people of Leicester; It is in the wrong place."

The relative walkability in the North was higher as measured by perceptions on the walking environment, area connectivity and access to services by walking and public transport. Distance to services, personal security concerns, cleanliness (state of the gardens, litter on the street), condition of pavements, lack of street lights and pedestrian crossings were problems highlighted in both the North and the South. These are likely to have a negative impact on the quality of the walking environment thus social capital. Using public transport to access services remained difficult, especially for those living in the South. In the North, distance to services was the main barrier to walking, exacerbated by a lack of time to access services by walking in general. In both the North and especially the South, accessing services located in the neighbouring areas by public transport remains difficult, as seen by the bus route map. Therefore, a combination of factors such as low car ownership, relatively poor public transport and low average household income and better access to services in the North have contributed to the higher level of social interactions within the area (refer Figure 4). This may have impacted the higher levels of participation in social activities and sense of belonging in the North, whilst the higher levels of trust in the South could be related to the higher income levels revealed by the residents as North being the 'dodge city' while the South was 'Texas'.

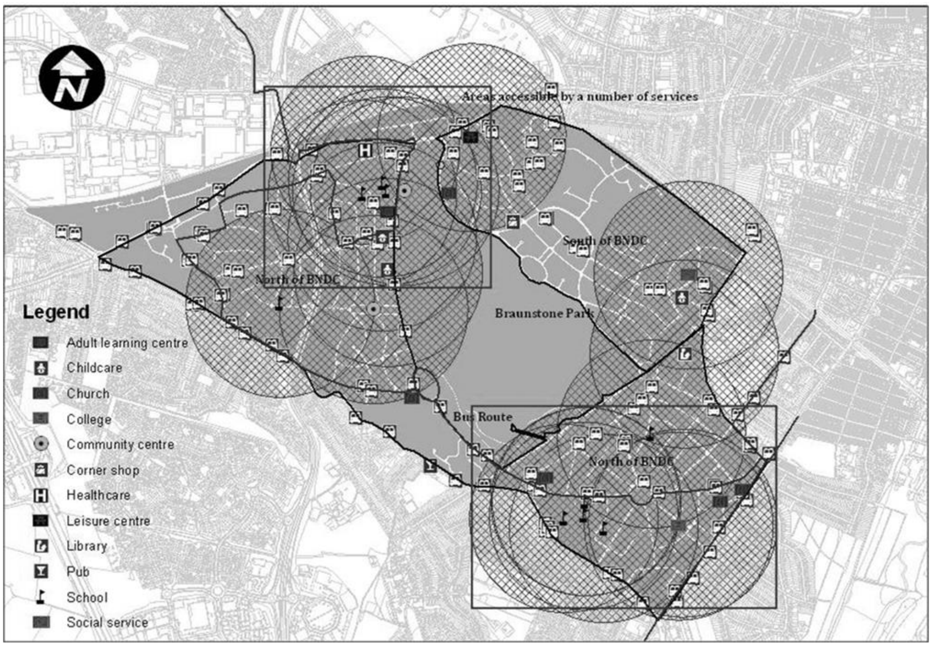

Figure 4: Relative Accessibility to the Services by Walking (Considering 400m Catchment Area for Each of the Services) in the BNDC Area.

4.5. *IMPROVING PERCEPTION OF NEIGHBOURHOOD*

The sense of belonging in the Braunstone neighbourhood had improved with a perceived higher quality of the physical environment compared to similar data from the MORI survey in 2008, but remains a problem. This is a positive sign in tackling the associated stigma which may prevent people from establishing long term residency in the area. Areas in which people choose to stay longer have distintive identities which is a good indicator of the potential to develop social capital. However, 'less pride' to be a resident of Brausntone points to underlying issues associated with 'stigma', rather than the change of the physical appearance of the area (refer Figure 5). The respondents held positive perceptions of the walking environment when views, landscaping, shade trees and design of the streets were considered of higher quality. The sense of pride in where one lives that creates feelings of belonging is an important contributor to social capital. This also influences the individuals' decision on local participation and networking. Therefore, the stigma associated with being a resident of Braunstone needs careful consideration if the estate is to integrate with Leicester City for longer term sustainability. Postive perceptions of the environments were expressed in statements such as "Brite centre is really good; We got a café there; Council offices are there; We spend hours there and have a laugh; Braunstone Leisure Centre, I've been there but don't use it; I've seen Braunstone improve; lot of facilities and even in winter they are used; Brite centre is far better than other libraries; The staff is good to anybody".

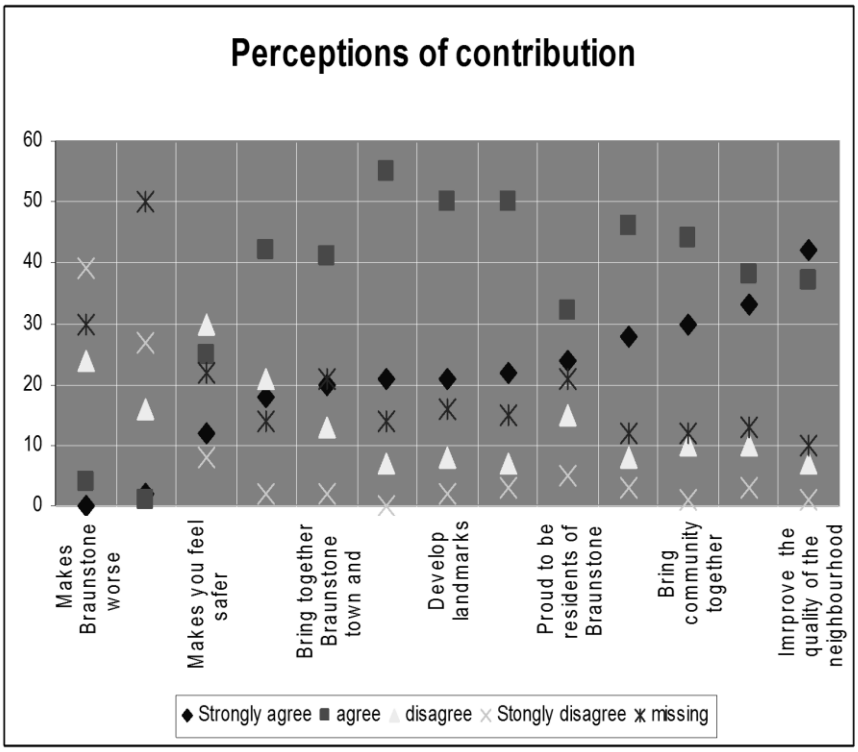

Figure 5: Perceptions of the Contribution of the Improved Physical Environment

5. CONCLUSIONS

Within the scope of the study we could not explore all themes and attributes that were proposed by SUE-MOT. However, it was clear that the walking environment, facilities and buildings, had provided opportunity for social interactions encouraging people to reside in Braunstone in the longer term. Several indicators and proxies used suggested that facilities and buildings, such as the Brite Centre and Braunstone Leisure Centre, have contributed to a varying degree of social interaction, mediating for a growth of social capital as expected. The new facilities have contributed to bringing more types of users into close proximity for the people of Braunstone. However, a more fine-tuned response addressing the specific needs of diverse groups such as the range of lifestyles and needs across the ages would increase levels of participation.

The importance of improving connections between the neighbourhoods and beyond was clear to retain people for longer term residency to develop social capital that improves well-being. The social division between the two communities living in the North and South was seen as a major problem for the area. Poor accessibility to services by walking and by public transport and the absence of a "Central Hub"/"Cultural Heart" together with socio-economic circumstances, may have contributed to the lack of social solidarity of the area as a whole. This need was clearly demonstrated by a respondent as "I use the facilities when I buy a one day bus ticket paying two pounds. It is not possible to get to these places otherwise."

Although the level of crime has significantly reduced in recent years, concerns about safety remain. The new facilities have not affected the pressing issue of safety in the eyes of the respondents. The nature of activities housed in buildings may prevent 'active frontages' for natural surveillance, as recommended by urban design guidance, but this is an important consideration in contexts such as Braunstone. In fact, lack of security was the perceived key barrier that discourages walking. These concerns may also contribute to poorer health outcomes, such as fear or anxiety (Huxley and Rogers, 2001) which in return negatively impact people's walking behaviour (Warwickshire County Council, 2006). Evidence suggests that the presence of over-grown trees, litter, graffiti, isolated environments and congregation of young people on streets can contribute to the fear of crime (Rodgers, 2009).

Overall evidence suggests that regeneration initiatives which tackled the underlying causes of the problems in Braunstone have helped to improve the quality of life in the area. Improvements to the physical environment has had a positive effect on social capital by providing opportunity for interaction and incentives to establish longer term residency in the area. As social capital theory suggests, the nature of social capital proves to be highly context specific and therefore physical attributes or urban design has to be holistically viewed. For example, the case study looked at the use of facilities and walkability that relates to movement structure, mixed use and local facilities. However, these issues were clearly connected to attributes that deal with diversity. This reiterates the need for a holistic view in sustainable regeneration because a 'one size fits all' approach cannot be prescribed. A bottom up approach from which solutions emerge through needs of the communities would still be the answer.

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University of Moratuwa – Department of Building Economics — www.becon.mrt.ac.lk

Building Economics and Management Research Unit (BEMRU), the research arm of the Department of Building Economics (DoBE) at the University of Moratuwa, Sri Lanka specializes in research in Building Economics and Management in the country as well as internationally. Established in 1990, the unit's specialization has strengthened and through collaboration with other organizations and institutes in the industry. BEMRU continued to develop and maintain close links with leading research institute around the world.

International Council for Research and Innovation in Building and Construction (CIB) — www.cibworld.nl

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GCU is the fifth largest university in Scotland which is also known as a deliverer of the highest quality education and research and to promote the "common weal". The School of Engineering and Built Environment of GCU provides undergraduate and postgraduate courses to suit the needs of industry and professions in the areas of construction, property and the natural environment.

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