The Second World Construction Symposium

SB 13

PROCEEDINGS

SOCIO-ECONOMIC SUSTAINABILITY IN CONSTRUCTION: PRACTICE, POLICY AND RESEARCH

14 - 15 June 2013

Colombo, Sri Lanka

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International Council for Research & Innovation in Building and Construction (CIB - W107)

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

International Initiative for a Sustainable Built Environment (iiSBE)

United Nations Environment Programme – Sustainable Buildings and Climate Initiative UNEP-SBCI

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THE SECOND
WORLD CONSTRUCTION SYMPOSIUM
2013

Theme:

Socio-Economic Sustainability in Construction: Practice, Policy and Research

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We are very thankful to the authors who have submitted papers for this symposium, as if not for them, we could not hold this event. 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, paper presenters, best paper award selection 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 Second World Construction Symposium 2013' a success.

Editors

The Second World Construction Symposium 2013
Sri Lanka
June 2013

PREFACE

The Second World Construction Symposium 2013 on 14 – 15 June 2013 in Colombo, Sri Lanka is jointly organised by the Ceylon Institute of Builders (CIOB); International Council for Research and Innovation in Building and Construction (CIB – SB13); International Initiative for a Sustainable Built Environment (iiSBE); United Nations Environment Programme-Sustainable Buildings and Climate Initiative (UNEP-SBCI); International Federation of Consulting Engineers (FIDIC) and, Building Economics and Management Research Unit (BEMRU). The main theme of this international research symposium is '*Socio-Economic Sustainability in Construction: Practice, Policy and Research'*. The symposium will provide a special forum for researchers and practitioners in the area of challenges for construction industry worldwide to share their knowledge, experience and research findings.

The sub themes of the symposium covered 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; and Sustainable Facilities.

We received number of abstracts and full papers for the symposium covering 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 for 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 and symposium organising committee members and that it would pave way for advancement of knowledge.

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A FRAMEWORK FOR ENVIRONMENTAL RATING SCHEMES FOR INFRASTRUCTURE PROJECTS

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ABSTRACT

Infrastructure plays a vital role in a country's socioeconomic development and there is a growing demand for infrastructure in developing countries. However, infrastructure development impacts the natural environment significantly. Therefore, it is important to consider the environmental sustainability of infrastructure projects. In the built environment sector, Environmental Rating Schemes (ERS) play an important role in evaluating and encouraging the implementation of sustainability at the project level. While ERSs have gained widespread attention worldwide, less attention has been paid to infrastructure, and it has tended to focus on the building sector. Furthermore, no ERSs for infrastructure are found in developing countries so far. It is important for an ERS to be type-specific and many building rating schemes have considered this. However, no type-specific ERS for infrastructure has been published so far. Moreover, the existing ERSs have been criticized for the absence of any theoretical bases. To address these gaps, this study aims to propose a theoretical framework for infrastructure ERSs in developing countries. The literature on environmental sustainability was reviewed to identify the important aspects which should be applied at the project level to achieve environmental sustainability in those countries. The factors were analyzed using Analytic Hierarchy Process (AHP). Results show the highest importance for minimising impacts of waste disposal and non-renewable energy sources followed by avoiding corruption. The study provides a theoretical basis for developing ERSs for infrastructure projects and a path for developing sector-specific ERSs.

Keywords: *Developing Countries; Environmental Rating Schemes (ERSs); Infrastructure Projects.*

1. INTRODUCTION

Infrastructure projects play a vital role in the economic and social development of a country. Urbanization and implementation of the country's development plans lead to growing demand for infrastructure. Organisation for Economic Co-operation and Development (OECD, 2006) reported that nearly half of the international financial institutions' lending to developing countries goes to infrastructure and it is likely to rise from the current $700 billion a year to $1 trillion a year by 2030.

However, there is also a dark side of infrastructure development. Such projects normally spread over wide geographical areas, utilize a large volume of natural resources, take a long time to construct (OECD, 2006) and significantly impact the natural environment. With the increasing demand for infrastructure, more attention should be paid to reduce the adverse environmental impacts of infrastructure development.

In achieving Environmental Sustainability (ES) in the built environment, environmental assessment methods play an important role by evaluating and measuring the environmental performance of projects. Crawley and Aho (1999) categorized these environmental assessment methods under Life-Cycle Assessment methods (LCA), Environmental Impact Assessments (EIA) and Environmental Rating Schemes (ERS) such as Building Research Establishment Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED). LCA methods consider buildings as products and assess life cycle impacts and are known as non-site specific assessments. EIA methods consider broad environmental impacts (Crawley and Aho, 1999).

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Among these assessment methods, ERSs have gained widespread attention since the launch of BREEAM in the United Kingdom in 1990. These schemes have been applied extensively in the construction industry. For example, BREEAM schemes have certified 15,000 projects since 1990 and the Building Construction Authority's (BCA) Green Mark schemes have certified 1180 building projects in Singapore since 2009. ERSs have gained wide attention in the developing countries as well. For example, in India, GRIHA has been used to certify 290 projects since 2008 and Green Building Index in Malaysia has been applied to certify over 26 million square feet of buildings since 2009. In Sri Lanka, the first green building rating scheme was launched in 2011. Some of these rating schemes have been specified and recognized by public agencies and by banking, financial and insurance companies as well (Cole, 2005). For example, some versions of the BCA Green Mark in Singapore are mandatory. If used effectively, ERSs can play an important role in evaluating and encouraging the implementation of sustainability principles at the project level.

2. KNOWLEDGE GAP AND RESEARCH PROBLEM

Not much attention has been paid to ERSs for infrastructure projects as they have tended to focus on buildings (Wong, 2010). There are many ERSs for assessing buildings in both developed and developing countries, but only a few of infrastructure ERSs have been published worldwide so far. These are: Civil Engineering Environmental Quality Assessment and Awards Scheme (CEEQUAL) in the United Kingdom (2003), the Building and Construction Authority (BCA) Green Mark for Infrastructure in Singapore (2009), Zofnass Rating System for Sustainable Infrastructure housed at Harvard University's Graduate School of Design (2011) and Australian Green Infrastructure Council rating system (2012).

CEEQUAL is specific to the United Kingdom and Ireland and the BCA Green Mark has been developed for application in the Singaporean context. All these countries have specified environmental standards and involved different contexts when compared with developing countries. An international version of CEEQUAL has been launched recently. However, no single infrastructure ERS is found in developing countries so far.

Moreover, many ERSs for assessing building projects have considered different types of buildings separately such as residential, commercial and so on. Also, project scale (Abdalla *et al*., 2011) and project type (Haapio and Viitaniemi, 2008) have been identified as important factors in categorizing assessment tools because different types of projects cause different environmental impacts. However, the published infrastructure ERSs are general to all types, and no type-specific infrastructure ERS has been published so far. This is a critical gap as, again, different types of infrastructure cause significantly different environmental impacts.

Despite the popularity gained and the wide application of existing ERSs in the built environment, these are not without criticisms. These include lack of overall transparency (Inbuilt, 2010 cited by Alyami and Rezgui, 2012), failure to cover some important criteria (Haapio and Viitaniemi, 2008; Abdalla *et al*., 2011) and lack of a clear path towards establishing type-specific and regional ERSs (Alyami and Rezgui, 2012). Also, no theoretical base has been established for ERSs in general (Cole, 1998; Retzlaff, 2009). Thus, in this area, theory lags behind practice. Crawley and Aho (1999) identified methodological transparency as an important requirement in developing ERSs, from both a philosophical and a practical point of view. However, previous studies have followed a process of listing sustainability criteria and sub-criteria under broad categories and ranking them with expert evaluation. Evaluating the project's impact on the natural environment (Crawley and Aho, 1999) is a primary objective of environmental assessment schemes. ERSs reward efforts to minimise such impacts and in some instances the efforts to enhance the natural environment as well. Therefore, the basis of ERSs should demonstrate the potential impacts of development activities on the natural environment. However, such a basis for ERSs has not been established so far.

3. AIM AND OBJECTIVES

The above review of works on ERSs and related studies shows that studies relating to infrastructure ERSs are lacking. Moreover, the absence of a theoretical base for the selection of the assessment criteria in these ERSs, and the weighting system is a cause of many shortcomings of existing ERSs. Motivated by these gaps, the research question addressed in the study was, “How can the criteria and weights in ERSs for infrastructure projects in Sri Lanka be determined?”

Following the research question, the aim of this study is to develop a framework as the basis for determining criteria and weighing of ERSs for infrastructure projects in Sri Lanka. The specific objectives of the study are to:

- identify the important factors for assessing environmental sustainability (ES) of infrastructure projects,
- propose a theoretical framework for ERSs in infrastructure sector, and
- make recommendations for further applications of the framework.

4. SCOPE OF THE STUDY

This study was carried out in Sri Lanka which was the geographical territory selected to represent developing countries with rapidly increasing demand for infrastructure development.

5. METHOD OF THE STUDY

The literature on Sustainable Development (SD) was reviewed to identify the relevant aspects which should be applied at the project level. This review directed attention towards Environmental Sustainability (ES) and the importance of the natural environmental for everything else to be sustained. Therefore, the literature on Environmental Economics was reviewed to identify the interactions between the economic system and ecological systems which are the root causes of environmental issues and should be considered in assessing the environmental performance of development activities, and hence of infrastructure projects as well. Other aspects that should be considered to ensure ES efforts with particular reference to developing countries which otherwise would be barriers to such efforts were also reviewed.

These identified factors were adopted as the factors to be considered in assessing the environmental performance of infrastructure projects in Sri Lanka. A cross-sectional survey was carried out using questionnaires, to measure the importance of the factors. A pair-wise comparison was employed and data were analyzed using the Analytic Hierarchy Process (AHP).

6. LITERATURE REVIEW

6.1. SUSTAINABLE DEVELOPMENT (SD)

SD is often presented as comprising three sectors; economic, environmental and social and often presented as shown in Figure 1.a. Giddings *et al*. (2002) pointed out several weaknesses of this ring model which shows three rings in a symmetrical interconnection that leads one to assume that the three sectors are separate or even autonomous from each other. Furthermore, Giddings *et al*. (2002) claimed that the model shows possible trade-offs that can be made among the three sectors, similar to that of the concept of “weak sustainability” which assumes that man-made capital can be used to replace or substituted for natural resources and systems (Neumayer, 1999 cited in Giddings *et al*., 2002; Daly, 1994) which is far beyond the reality within real physical environmental limits.

In reality, the economic system depends on society and the environment and ultimately both the economic system and society depend on the natural environment. The natural environment is the core of any economy, and economies cannot be sustained without environmental goods and services.

Therefore, ES is a necessary condition for economic sustainability (Thampapillai, 2002). Thus, the separation in the ring model underplays the fundamental connections between the economy, society and the environment (Giddings *et al*., 2002) and it is suggested that the nested model (Figure 1.b.) represents the reality of the relationships between three sectors better than the ring model (Giddings *et al*., 2002).It has been realized today that the term "economic" does not just mean the happenings in the flow of money but also changes in human well-being which comprise not only monetary wealth but also many other services provided by the natural environment. Therefore, effective sustainability approaches need to address the relationships between ecosystems and economic systems (Jansson *et al*., 1994).

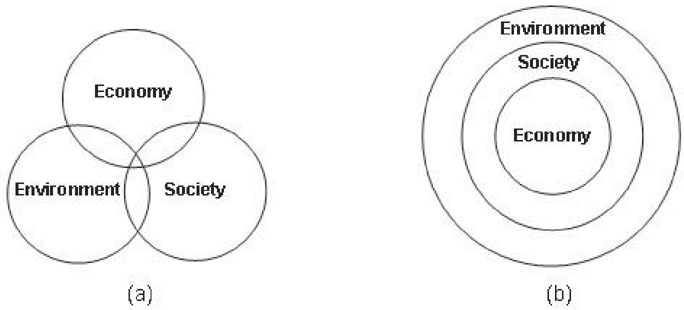


Figure 1: Ring model and Nested model (Giddings *et al*., 2002)

This fact should be considered in environmental assessments and ERSs should include the factors to address these interactions. Therefore, the literature on the interactions between the ecological system and the economic system was reviewed and will be presented in the next section.

6.2. INTERACTIONS BETWEEN NATURAL ENVIRONMENT AND ECONOMIC SYSTEM

The major interactions between the economic system and the natural environment are discussed to establish the requirements for ES for the proposed model. Such interactions identified by several authors in the field of Environmental Economics are summarized in the Table 1.Since the concern of this study is to propose changes to the current patterns of economic activities to achieve ES, the interactions are listed from the perspective of impacts of the economic system to the natural environment whether positive or negative.

These major interactions which provide the basis of the theoretical framework for the assessment of ES of infrastructure projects will review below.

6.2.1. USE ENVIRONMENT AS A SOURCE OF LAND

Although land could be considered as a unique resource that it is perfectly inelastic in supply and available to society as a fixed total quantity (Hanley *et al*., 2001), with the rapidly growing development activities, there is a greater concern about changing land quality (FAO, 1997). The way land is used highly affects the future availability of productive land in terms of both quantity and quality. Therefore, minimising land use in terms of area and considering the composition of the land (whether it is a greenery area, wetland, marshy land and so on) are important for environmental sustainability and therefore, considered in the theoretical framework in this study.

6.2.2. USE ENVIRONMENT AS A SOURCE OF MATERIALS AND ENERGY SOURCES

The environment provides inputs to the economic system; raw materials and energy resources (Hanley *et al*., 2001) for both production and direct consumption (Common and Stagl, 2005; Asafu-Adjaye, 2005). The earth is considered as a closed system in terms of materials and receives a limited amount of outside energy (solar energy) within a certain period. Therefore, natural resources are considered as scarce resources and with growing developmental activities they become scarcer. At the same time, materials extraction causes damages to the environment. For example, quarries developed in national parks will damage the biodiversity and amenity flow (Hanley *et al*., 2001) rather than one in a brown-field area. Logging in a rainforest largely impacts biodiversity compared to a logging in a planted forest. It might involve the extraction of the same amount of materials by quantity but cause different harms. Similarly, the type of materials should be considered whether harmful or not. Hazardous materials cause larger damages to the environment than compared to a same amount of non-hazardous materials.

These aspects are applicable to non-renewable energy sources as well. Therefore minimizing the usage of materials and non-renewable energy resources by quantity, damages during extraction and during selection are considered as major requirements for ES in the theoretical framework in this study.

Table 1: Summary of Literature Review of Economic - Ecosystem Interactions

Interactions	Sources
1. Use the environment as a source of land	Pearce and Turner (1990); de Groot (1992); Turner *et al*. (1994);
2. Use the environment as a source of materials and energy resources	Pearce and Turner (1990); de Groot (1992); Daly (1994); Turner *et al*. (1994); van den Bergh (1996); Lovins *et al*. (1999); Hanley *et al*. (2001); Thampapillai (2002); Common and Stagl (2005); Asafu-Adjaye (2005)
3. Use the environment as a sink for disposing of waste	Pearce and Turner (1990); de Groot (1992); Daly (1994); Turner *et al*. (1994); van den Bergh (1996); Lovins *et al*. (1999); Hanley *et al*. (2001); Thampapillai (2002); Common and Stagl (2005); Asafu-Adjaye (2005)
4. Use the environment as a flow of amenities and life support services	de Groot (1992); Turner *et al*. (1994); Hanley *et al*. (2001); Thampapillai (2002); Common and Stagl (2005); Asafu-Adjaye (2005)
5. Invest in natural capital	de Groot (1992); Daly (1994); Lovins *et al*. (1999); Thampapillai (2002)
6. Conserve biodiversity	Hanley *et al*. (2001)

6.2.3. USE ENVIRONMENT AS A SINK FOR DISPOSING OF WASTE

The natural environment provides materials and energy sources for both production and consumption. In production processes, useful products are made and residuals are also generated. When these residuals are not inserted again into the economic system by reusing or recycling, they become waste (Common and Stagl, 2005). Similarly, useful products become waste after consumption. Waste cannot be destroyed in an absolute sense and also not possible to recycle all waste as explained in Environmental Economics theories according to the first and second laws of thermodynamics respectively. Hence, eventually be discharged into the environment (Turner *et al*., 1994; Thampapillai, 2002). When the disposal of the waste is continuous, intense, and exceed the "assimilative capacity" (the capacity that the natural environment is able to handle waste) (Thampapillai, 2002), then it is no longer able to fulfil its functions as a waste sink. This affects other functional performances of the natural environment consequently and imposes limits to economic and development activities (Turner *et al*., 1994; Common and Stagl, 2005). Both the quantity and the quality of waste disposal and also the location should be considered to ensure environmental sustainability. For example, the discharging of non-treated water into a river system is more harmful than that of the same quantity of treated effluent. Hence, these factors are considered in the proposed theoretical framework.

6.2.4. INVEST IN NATURAL CAPITAL

It is not possible to attain a target of zero harm to the environment during economic and development activities. Therefore, a way to compensate for the harm to the environment should be included in economic activities. Thampapillai (2002) suggested the reinvesting part of the income generated in the economic system in the natural environment. This takes the form of compensation for what the economic activities consume. This investment in natural capital can take several forms including: to maintain the flow of services of endowments that currently provide services (functional), to restore the flow of services from endowments which have ceased to provide services (non-functional), or to create new natural capital. The first form is similar to offsetting wear and tear of capital goods. Cleaning up a polluted river periodically and reforestation are examples of these forms, respectively. Daly (1994) emphasizes the importance of the latter, in order to cope with the increasing demand for environmental goods and services. Therefore, investing in natural capital to maintain its status and to enhance its stock are important requirements for ES and are considered in the proposed theoretical framework.

6.2.5. IMPACT BIODIVERSITY

According to Hanley *et al*. (2001), biodiversity loss involves more than the loss of particular species. Direct impacts such as loss of genetic materials for food crops or as a source of medicine, loss of a range of ecosystem services and, impacts on non-use benefits such as aesthetics can also be experienced. Biologically diverse ecosystems provide a greater flow of ecosystem services than non-diverse systems (Parker and Cranford, 2010). Also, diversity provides an important property of natural systems which is known as ‘resilience’, the ability to withstand shocks such as drought and fire (Hanley *et al*., 2001). Although natural resources are conserved in terms of quantity of total natural capital stock, the diversity of that natural capital stock is of importance in order to continue the functionality of the life-supporting ecosystems (Wilson, 1988 cited in Jansson *et al*., 1994). Hence, conserving biodiversity and reducing negative impacts on biodiversity are regarded as major requirements for ES in the proposed theoretical framework.

6.2.6. USE ENVIRONMENT AS A FLOW OF AMENITIES AND LIFE SUPPORT SERVICES

People derive utility in terms of happiness and satisfaction (Common and Stagl, 2005; Hanley *et al*., 2001) through amenity services provided by the natural environment including sightseeing, sunbathing, wilderness recreation and so on (Hanley *et al*., 2001; Common and Stagl, 2005). Negative impacts on natural resources disturb the functioning of ecological systems and these amenities. The natural environment also provides biophysical necessities of life such as food, energy, mineral nutrients, air and water (Jansson *et al*., 1994) through life-support services including climate regulation, operation of the water cycle, regulation of atmospheric composition, nutrient cycling, and so on (Hanley *et al*., 2001). Maintaining the life support services of the environment is important for the survival of humankind.

Since land use, resource use, waste disposal and loss of biodiversity which are discussed in the previous sections, are the causes of the disruption of the amenities and life-support services, controlling those causes during development activities will help in continuing the amenities and life support services as well and thus they are not duplicated in the proposed framework

6.3. OTHER FACTORS TO ENSURE ENVIRONMENTAL SUSTAINABILITY EFFORTS

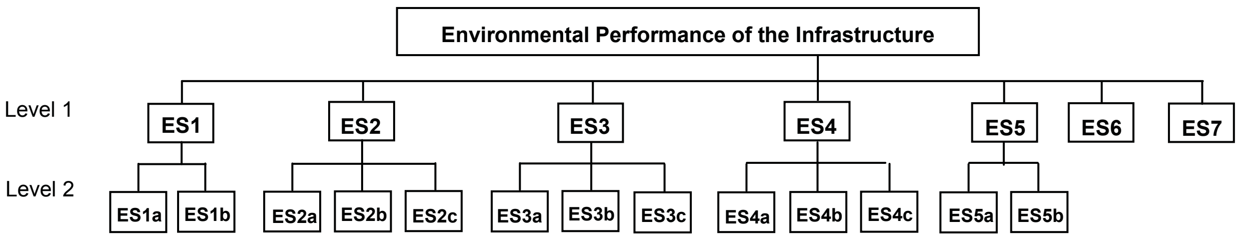
The factors identified in the previous sections are ecological factors that contribute directly to minimising impacts on the natural environment and to enhancing its status. Several researchers have claimed that the scope of ERSs should be broadened to embrace the wider agenda of sustainability as a necessary requirement (Haapio and Viitaniemi, 2008). However, the review of the literature on SD in section 6.1 revealed that the natural environment should be sustained for everything else to be sustained, but it is hindered in developing countries due to the priorities given to economic and social issues. Therefore, rather than inserting economic and social performances, this study reviewed such critical socio-economic barriers to ES efforts. As a result, two major factors, namely poverty and corruption, are considered in the theoretical framework, and are now discussed.

6.3.1. *Eradicate Poverty*

"The Future We Want", the report of the Rio+20 United Nations Conference on Sustainable Development, emphasizes the eradication of poverty as an indispensable requirement for SD today (UNCSD, 2012). However, this is not a new issue. Eradicating extreme poverty and hunger is Goal One of the Millennium Development Goals declared by the United Nations. Goodland and Daly (1993) claimed that reduction of poverty is a must for ES. In a study of the poverty-environment relationship for rural households in Zimbabwe, Cavendish (2000) found empirical regularities to show that poorer households heavily depend on environmental resources for income generation. A study in Nigeria by Akinola *et al*. (2012) showed that the eradication of poverty is a solution for attaining ES and otherwise the poor degrade the environment and its resources. Although not frequently addressed in ERSs, poverty eradication can be addressed to some extent at the project level as well. World Bank (2012) provides some examples such as investing in local agriculture, creating jobs, expanding nutrition programs and enhancing education in the locality. Although eradicating poverty would not solve all the global environmental problems, in developing countries, this is one of the requirements to achieve ES in developing countries. Otherwise, it will become a barrier to such efforts. It is important to promote such efforts in development projects and it is possible to address them through ERSs. Therefore, it is included in the theoretical framework in this study.

6.3.2. *Avoid Corruption*

Corruption enables individuals to avoid environmental regulations (Transparency International, 2008) and hence, hinder conservation efforts and endanger the environment (Robert and Walpole, 2005). The Rio+20 report stresses that fighting corruption at both the national and international levels is a priority because corruption is a serious barrier to SD. Corruption can take place in different stages and in different forms. Although high-level political corruption is difficult to address at project level, the project stakeholders can ensure that they are not involved in any such activities within the project, either taking bribes or giving bribes. Although not noted so far, ERSs can address such issues by imposing demerit points on the projects on which any corrupt activities were involved. Hence, "avoid corruption" is considered in the theoretical framework of this study.



ES 1 – Minimize the impacts of land use
- minimise the area utilise (ES1a)
- minimise damages to composition (ES1b)

ES 2 – Minimize the impacts of materials usage
- minimise amount of material usage (ES2a)
- minimise damages during extraction (ES2b)
- minimise damages due to harmful types (ES2c)

ES 3 – Minimize the impacts of usage of non-renewable energy sources
- minimise amount of usage (ES3a)
- minimise damages during extraction (ES3b)
- minimise damages due to harmful types (ES3c)

ES 4 – Minimize the impacts of waste disposal
- minimise amount of waste disposal (ES4a)
- minimise damages due to negative quality of waste (ES4b)
- minimise damages due to location of disposal (ES4c)

ES 5 – Invest in natural capital
- to maintain it (ES5a)
- to enhance it (ES5b)

ES 6 – Conserve biodiversity

ES 7 – Eradicate poverty

ES 8 – Avoid corruption

Figure 2: Proposed Framework for ERSs

6.4. THEORETICAL FRAMEWORK

By considering the impacts on the natural environment due to economic and development activities and the other factors to be considered to ensure the ES efforts, seven major factors and several sub-factors which are important to achieve ES of infrastructure projects were determined. These are illustrated in a hierarchical structure in Figure 2. These are the factors to be considered when assessing the environmental performance of development projects, thus providing the theoretical base for infrastructure ERSs.

7. DATA COLLECTION AND ANALYSIS

Data were analysed using the AHP method. The AHP literature states that the sample size is not critical if the representativeness of the sample is secured (Wind and Saaty, 1980 cited Kim and Kim, 2009) and it is not necessary for the study to involve a large sample (Wong and Li, 2008). To ensure the representativeness and reliability of data, questionnaires were distributed among a group of environmental experts consisting of 20 professionals working in the infrastructure sector with environment-related experience who have obtained post-graduate academic qualifications in environmental studies.

Although market based, voluntary environmental rating schemes seek stakeholder participation and expert opinion from a diverse group such as Architects, Civil Engineers, Quantity Surveyors and also Clients to include the architectural, technical, financial and other aspects to increase the application and to analyze the adoptability, it may compromises the fundamental environmental conservation perspective. Since this study addresses the issue of absence of a theoretical base for ERSs, it was expected that the respondents should have specific knowledge; the knowledge on environmental issues related to infrastructure sector in environmental conservation perspective and allocate weight to each factor based on their opinion on the severity/importance of such impacts in the country.

The key factors of the study were explained to the sample group prior to their participation in the study, in order to avoid misunderstanding and to ensure the reliability of data. The questions were structured in a way that facilitates pair-wise comparisons of environmental problems and positive environmental impacts and compared each pair of factors in both levels of the hierarchy shown in Figure 2. AHP is as a structured method for decision making and for solving problems by dealing with complex, unstructured and multiple-attribute decisions which considers decision variables or decision attributes, at least some of which, are qualitative, and cannot be directly measured (Partovi, 1992; Saaty and Vargas, 2001).

Table 2: Results of AHP Analysis

Main factors (Level 1)	**Relative importance**	**Normalized (Xn)**	**Sub factors (Level 2)**	**Normalized (x_n)**	**Sub factor weighting (Xn)* (x_n)**
ES1	0.889	0.091	ES1a	0.48	0.44
			ES1b	0.52	0.48
ES2	0.820	0.084	ES2a	0.89	0.25
			ES2b	1.03	0.29
			ES2c	1.10	0.31
ES3	1.766	0.181	ES3a	1.23	0.73
			ES3b	0.90	0.54
			ES3c	0.91	0.54
ES4	2.054	0.211	ES4a	0.90	0.63
			ES4b	0.93	0.65
			ES4c	1.19	0.83
ES5	0.886	0.091	ES5a	0.76	0.69
			ES5b	0.24	0.22
ES6	1.138	0.117			
ES7	0.825	0.085			
ES8	1.364	0.140			
Total		1.000			

8. RESULTS AND DISCUSSION

Table 2 shows the normalized relative importance of each factor as obtained from the analysis using the AHP method. Waste disposal is the major problem identified, followed by the usage of non-renewable energy sources, and then corruption. The first two factors represent the most critical environmental problems in developing countries today.

The results suggest that it is important to avoid corruption to enhance the environmental performance of infrastructure; this is the case in many developing countries, as is also found in the literature. The location of the waste dump is critical among the sub-factors under the impacts of waste disposal and quantity of usage of non-renewable energy sources among ES3 sub-level issues.

9. CONCLUSION AND FURTHER APPLICATION

This study examined the factors to be included in ERSs for assessing the environmental performance of infrastructure projects in Sri Lanka. The literature review on SD showed that ES is important for everything else to be sustained. ERSs evaluating environmental performance and should embrace the minimisation of the negative impacts of development activities the natural environment, and on the enhancement of the positive impacts. Therefore, an impact-oriented approach was followed in the study and factors were identified through a review of interactions between the natural environment and the economic system. A survey was carried out to measure the relative importance of factors through a pair-wise comparison and AHP method was used to analyse the data. The results showed the relative importance of factors that should be considered in ERSs for Sri Lankan infrastructure projects, with the three most significant factors being minimising impacts of waste disposal, usage of non-renewable energy sources, and avoiding corruption. This framework can be applied to a specific infrastructure project type to develop type-specific ERSs. The current environmental problems and potential positive impacts of the project type can be identified and categorized under each ES factor in the proposed framework as the next hierarchical level. Experts in the sector can be asked to rank the importance of each type-specific factor under the ES factors and multiply by ES factor weighting to obtain final weighting. The study is the first to address the absence of a theoretical framework for ERSs in the built environment and it provides a path for establishing type-specific and regional ERSs based on an impact-oriented approach.

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ABILITY OF BIM TO SATISFY CAFM INFORMATION REQUIREMENTS

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ABSTRACT

Facilities Management (FM) and Building Information Modelling (BIM) are contemporary day concepts that have modernised the way built environment behave. In modern day, FM concepts are moving towards to sustainable FM (SFM). Incidentally, Facilities Managers (FMs) become responsible for assuring the sustainability of facilities of the business. Modern day buildings are increasingly sophisticated and the need for information to operate and maintain them in sustainable manner is vital. Currently FMs rely on the information of the facility retrieved from conventional Computer Aided FM (CAFM). However, FM professionals face challenges from existing information inefficiencies resulting in unnecessary costs, productivity, efficiency and effectiveness losses where these leads to failure of SFM. Considering its favourable features, BIM had been identified as promising solution to effectively reach SFM goals. BIM conceptually has been developed to overcome the inefficiencies in conventional building information systems and recording methods. Combined data would enable the art of making any building more intelligent and sustainable. Significant efforts were found which had focused on getting the benefit of BIM for FM. However, there was no certain answer to "how far could BIM satisfy the information needs of CAFM?'' This paper proposes a methodology to theoretically answer this question, which had been proposed for the next step of the study being conducted in Sri Lanka.

Keywords: *Building Information Modelling (BIM); Computer Aided Facilities Management (CAFM); Facilities Managers (FMs); Sustainable Facilities Management (SFM).*

1. INTRODUCTION

Facilities Management (FM) and Building Information Modelling (BIM) are contemporary day concepts that have modernised the way built environment behave. These two concepts are vital in the rapid changing world to track the facilities effectively. Managing the non-core activities are mandatory in order to function efficiently and effectively in Facilities Managers' (FMs') day to day operations who relies on the accurate information of the facility retrieved from Computer Aided FM (CAFM). CAFM still largely based upon the conventional methods such as tabulated data and 2D (two dimensional) drawings. Consequently adopting a three dimensional capabilities with the object oriented database offered by BIM to the CAFM is vital for FM to manage information at their fingertips. Therefore, a research was initiated to study how well BIM can satisfy CAFM's building information needs. This paper is based on the literature synthesis presenting preliminary findings of this ongoing research, while also identifying specific challenges faced by researchers living in a less developed industry.

2. FACILITIES MANAGEMENT

Sustainability of the built environment depends on involvement of the operation and delivery of services within occupied environments. FM is becoming an increasingly important role in the built environment. FM covers a wide range of disciplines in built environment. FM is the integration of people, place and processes within an organisation to maintain and develop the non-core services which support and improve the effectiveness of its core business activities (British Institute of Facilities Management [BIFM], 2013). The effective management of the facilities services required a

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multi-disciplinary person who is called Facilities Managers (FMs). FMs have extensive responsibilities for providing, maintaining, and developing myriad services. FMs could be identified as hybrid management discipline that combine people, property and process management expertise to provide vital services to support of the organization (Shiem and Then, 1999).

2.1. FUNCTIONS OF FACILITIES MANAGERS

The FMs functions are mostly concern in four core areas (Barrett and Baldry, 2003) as shown in Figure 1.

Facility planning	**Real estate and building construction**	**Building operations and maintenance**	**General/office services**
• Strategic space planning • Set corporate planning • standards and guidelines • Identify user needs • Furniture layouts • Monitor space use • Select and control use of furniture • Define performance measure • Computer-aided facility management (CAFM	• New building design and construction management • Acquisition and disposal of sites and buildings • Negotiation and management of leases • Advice on property investment • Control of capital budgets	• Run and maintain plant • Maintain building fabric • Manage and undertake adaptation • Energy management • Security • Voice and data communication • Control operating budget • Monitor performance • Supervise cleaning and decoration • Waste management and recycling	• Provide and manage support services Office purchasing (stationery and equipment) • Non-building contract services (catering, travel, etc.) • Reprographic services • Housekeeping standards • Relocation • Health and Safety

Figure 1: FMs' Functions (Source: Barrett and Baldry, 2003)

2.2. THE CORE COMPETENCIES OF FACILITIES MANAGERS

According to IFMA (2013), communication, emergency preparedness and business continuity, environmental stewardship and sustainability, finance and business, human factors, leadership and strategy, operations and maintenance (O&M), project management, quality management, real estate and property management and technology are the core competencies of FMs. By looking at these competencies and functions, it is clear that FM is an umbrella term which covers a wide range of properties and user related functions in a built environment (Kamaruzzaman and Zawawi, 2010).

2.3. CURRENT PRACTICES AND STATUS OF FM

As building become more complex and high tech, user expectations rise and the pressure on FMs to perform increases (Alexander, 2000). The FM industry encompasses an array of complex tasks and soft services all of which have a very high dependency on the prompt availability of relevant information. Currently FMs are continually faced with the challenge of improving and standardizing the quality of the information they have at their disposal, both to meet day to day operational needs as well as to provide upper management reliable data for organizational management and planning (Sabol, 2008). The above challenges have become severe due to current practices of FMs. To perform these functions within the organisation FMs use the CAFM as their management tool. The input data for CAFM is acquired from diverse professionals in built environment right after completion of construction. It leads tediousness, lack of accuracy and blunders.

Whole Life Cycle (WLC) information is essential to support the O&M and asset management by the owner or FMs (East, 2012). Smith (2010) stated that problems related to O&M of buildings currently FMs are dealing with are: facilities are costly to operate, use a lot of energy and water, produce a lot of waste during the building process, and FM cannot control costs very well, timely information is rare, too many change orders, inaccurate drawings, high cost, increasing poor quality, buildings often end up in litigation and duplicates in data collection. All these problems are directly related to lack of or poor quality of information. As Christopher and Hodges (2005) stated that the above problems raise the need for Sustainable Facilities Management (SFM). SFM defined as,

> The process of integrating the people, place and business of an organization that optimises economic, environmental, and social benefits of sustainability (IFMA, 2012).

3. COMPUTER-AIDED FACILITY MANAGEMENT (CAFM)

CAFM is the support of FM by Information Technology (IT). CAFM includes the creation and utilization of IT based systems in the built environment (James and Watson, 2011).

According to CAFM Explorer (2013), CAFM modules are mainly grouped as following software,

- Computerised Maintenance Management System (CMMS) software that is used for Planned Preventive Maintenance, Reactive Maintenance and Asset Management.
- Resource booking software used for room booking, catering, equipment, and visitor management.
- Health and Safety software used for recording accidents or incidents, permit management, security and risk assessments.
- Supporting software used for stock, purchase ordering, digital dashboard and invoicing.
- Integrated Workplace Management System (IWMS) software used for space planning and management.
- Real Estate (RE) and Capital Planning software.

Integrated CAFM with CMMS software, Resource Booking Software, Health and Safety Software, Real Estate and Capital Planning software, Supporting Software and IWMS increase productivity and efficiency in FM (Alexander, 2000). CAFM evolves significantly to address all the operational challenges in FM industry (BIMhub, 2013). Janssen (2010) defined CAFM as,

> The use of information technology to effectively manage physical facilities in various ways.

According to Judicial Council of California (2001), CAFM performs the following functional supports,

- Project management
- Portfolio management
- Facility management or Maintenance management, and
- Real property management

and according to BIMhub (2013), CAFM contain following features,

- Centralised data
- Ability to report data
- Ease of data auditing
- Take better informed decisions
- Better management of O&M
- Efficient identification and allocation of tasks for the FM staff
- Regulatory compliance, and
- Improved sustainability

3.1. DEFICIENCIES OF CAFM INFORMATION TO CATER FM REQUIREMENTS

Today FMs often spend unnecessary amount of time looking for information in order to fix a facilities O&M problems. The FMs need to ensure that a balance is maintained between the capital and running costs of the information system and the value of the information generated (Alexander, 2000). Furthermore Alexander (2000) argued that the information in a built environment should enable better informed decision making at strategic, tactical and operational level.

It is suggested that a useful way of focusing information systems and the IT that serves FMs is to orientate them towards the best decision making processes. For this objective to be achieved, the information system should be sensitive to the FMs' responsibilities as well as to all organisational elements which have an indirect or direct impact upon the performance of the FM function. FMs should develop information systems and IT solutions which appreciate the differing types of decisionmaking processes and their associated information requirements (Barrett and Baldry, 2003). Transitions from design to construction and to operation result in loss of data added cost to reconstitute the data and overall reduction in data integrity (Autodesk Inc., 2008). This information could be hard to get and hard to use or is not corresponding to the real life situation (Gokstorp, 2012)

Alexander (2000) accentuated that present CAFM does not consider the strategic requirement of the facilities nevertheless its concern are only for O&M. This results in failure of using CAFM by top management for the purpose of decisions making capabilities. Moreover according to Ahmed, et al. (2012) CAFM has the lack of monitoring performance of the building. Information is not free and it is costly to collect, verify and maintain. Further, it has to be defined the stakeholders, requirements and priorities determine criteria, health or life safety requirements, regulatory requirements and business justification (Schley, 2012). The limited graphic capabilities of data centric applications of CAFM have focused mainly on space management rather than other functions (BIMhub, 2013). The challenge for FMs is to overcome these obstacles by utilizing the resources available; and convincing leadership, efficiencies and cost savings can be achieved with investments in technology, such as a well-planned CAFM system. It will be best initiate by integration of CAFM with BIM.

4. BIM

National Institute of Building Sciences (2007, p. 21) defines BIM as

> BIM is a digital representation of physical and functional characteristics of a facility.

It is also called as the "Electronic Owner's Manual" (Chobot, 2012) for simple comprehension. Figure 2 shows that types of data in the BIM. These data helps to FMs to perform their work. It is incorporated huge amounts of service, maintenance and cost information. The model includes all information about objects within the building such as Mechanical Electrical and Plumbing (MEP) system and importantly the relationship between them in a single repository (Sabol, 2008). BIM data are extracted in a COBie format, which is a standard that used to handover the BIM Design to FM.

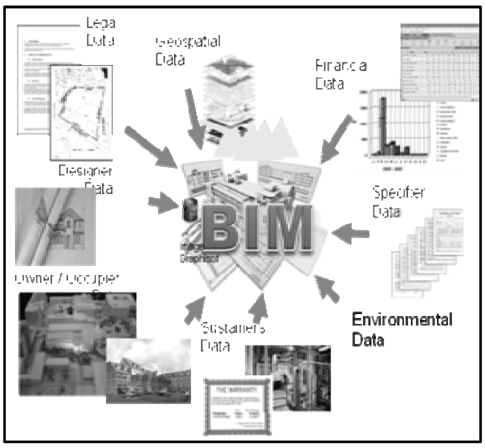

Figure 2: BIM Data (Source: Schley, 2013)

4.1. CONSTRUCTION OPERATIONS BUILDING INFORMATION EXCHANGE (COBIE)

Construction Operations Building information exchange (COBie) is a vehicle for sharing predominantly non graphic data about a facility. The primary motivation for the use of COBie is to ensure that the Client as owner or FMs receives the information about the facility in as complete and as useful form as possible (East, 2012). The primary COBie addresses the handover of information between the construction team and the owner. It deals with O&M, as well as more general FM information (Earley, 2012). COBie is an information exchange specification for the life cycle capture and delivery of information needed by FMs (East, 2012). This information is provided cumulatively during the design, construction, commissioning and handover phases (East, 2012). It combines data from designers, as they define the design and then by contractors as the building is constructed. It categorises and structures the information in a practical and easy to implement manner. Furthermore East (2012) found COBie can be viewed in design, construction and maintenance software as well as in simple spread sheets. COBie comprises sheets that document the facility, the levels or sectors, spaces and zones that make up the function of the facility. These are then filled with the actual manageable systems and assets and details of their product types.

Table 1 explains the required data in the each and every phase of COBie deliverables. There are eight phases and end of each phase, information must be transferred to owner or FMs

Table 1: COBie Data (Source: Whole Building Design Guide, 2009)

COBie Phase	Required COBie Information
Architectural programming phase	1. Contact worksheet 2. Facility worksheet 3. Floor worksheet 4. Space worksheet 5. Zone worksheet 5.1 Circulation zone 5.2 Lighting zone 5.3 Fire alarm zone 5.4 Historical preservation zone 5.5 Occupancy zone 5.6 Ventilation zone
Architectural design phase	1. Type worksheet 2. Component worksheet 2.1 Component records for interior doors and windows 2.2 Manufacturer information in component worksheet 3. Attribute worksheet. 4. Coordinate worksheet
Coordinated design phase	1. Type worksheet 2. Component worksheet 3. Manufacturer information in component worksheet 4. System worksheet 4.1 Fire protection zones 4.2 Intrusion detection zones 4.3 HVAC service zones 4.4 Plumbing service zones 4.5 Electrical service zones 5. Coordinate worksheet 6. Connection worksheet

COBie Phase	Required COBie Information
Construction documents phase	1. Spatial assets 1.1 Gross area 1.2 Net area 1.3 Floor covering type 1.4 Wall covering type 1.5 Ceiling type 2. Manufacturer information in component worksheet 3. Fixed assets 4. Document worksheet 5. Attribute worksheet
Construction mobilization phase	Document Worksheet
Construction 60% complete phase	1. Subcontractor contact information 2. Manufacturer contact information 3. Room tag 4. Manufacturer information in type worksheet 5. Installed material, products, and equipment 6. Government furnished products 7. Bar codes. 8. Approved submittals 9. Submittals remaining to be approved 10. Attribute worksheet
Beneficial occupancy phase	1. Spatial assets 1.1 Gross area 1.2 Net area 1.3 Floor covering type 1.4 Wall covering type 1.5 Ceiling type 2. Equipment assets. 3. Parts and warranty contacts 4. Warranty information 5. Replacement parts 5.1 Detailed parts set 5.2 Replacement parts diagrams 6. Operating plans. 6.1 Operator prestart 6.2 Start up, shutdown, and post-shutdown procedures 6.3 Normal operations. Provide narrative description of normal operating procedures 6.4 Operator service requirements 6.5 Operating instructions 7. Building services descriptions 8. Preventive maintenance 9. Emergency operations 9.1 Troubleshooting instructions 10. Safety instructions 11. Final approved submittals and documents 12. Coordinates. 13. Products and equipment attributes
Fiscal completion	Updated previous phase information, as needed

Objective of the COBie is to improve the life cycle building information interoperability using commercially available releases of BIM. But all the details are described above are in a form of spreadsheet. There will also be a need to have a more robust system for processing the information as understanding and needs grow (Department of Business Innovation and Skills, 2011). BIM data delivered to owners in a form of COBie. Sophisticated system should be available to receive, share, store and process COBie data. Doing this without proper systems will be a difficult task for FMs in incorporating them to their day to day work. There is a need for user interface to the data to facilitate to FMs. This could be done by CAFM. Since this is an unknown fact, the next section explores the capability of CAFM to do so.

4.2. CAFM INTEGRATION WITH BIM

CAFM systems can be easily integrated with BIM for information transfer from the Architectural Engineering Construction industry to the FM (ACE/FM) industry (BIMhub, 2013). Integration of CAFM into BIM includes not just design and construction phase information as well as complex work order management systems and tenuous maintenance schedules, which encompasses the impact of facilities management on the entire business (BIMhub, 2013). The Figure 3 illustrates the group of integrated CAFM which are IWMS, CMMS and RE and Capital Planning software. This is called as BIM integrated CAFM (BIMCAFM).

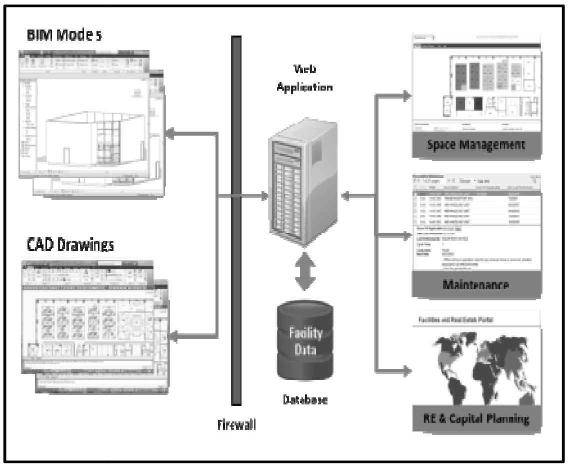

Figure 3: BIM & CAFM Integration
(Source: Smith, 2010)

Therefore the BIMCAFM mitigate the previously mentioned problems in present CAFM.

- Can be used as a strategic decision making tools because it has all the data ragarding sustainability (Schley, 2013).
- Complex data can now be stored, retrieved, combined, and analysed in BIMCAFM.
- It can be explore where the exactly problem occures regarding asset location of the place can be knows by BIM.

4.3. BENEFITS OF BIM INTEGRATED CAFM (BIMCAFM)

BIM is a way to create better designed better managed and longer lasting sustainable facilities (BIFM, 2012). When BIM is integrated with CAFM it creates a favourable environment to carry out FMs function in an effective manner.

Specific benefits of BIM to FM include,

- Fostering faster and more effective FM by providing information that is easily shared and reused by the variety of contractor and staff employed in the organization.
- Ability to control WLC and environmental data leads to predictable building
- Enhanced information for emergency preparedness
- Increased building performance and quality

- Improved collaboration using Integrated Project Delivery (IPD)
- Improvement of building analysis, energy efficiency and sustainability
- Improved commissioning and handover of facility information
- Better management and operation of facilities (Eastman *et al.,* 2011)

Therefore if the FMs Paying attention to building systems, maintainability, operating costs, energy management, staffing and organizing, turnover procedures and training, as built drawings, warranties, and sample books during construction; it will help ensuring that the organisation will assume an operable building at turnover and that initial operating problems will be minimised. This can be achieved by the BIMCAFM (Cotts *et al.,* 2010). Using BIMCAFM enables FMs to meet with the growing need for better information flow and standardization of operational data. Earlier, the CAFM system was used to collect data mainly from the design team. Now, with the BIMCAFM more detailed information is reported to FMs, so that the FMs can use this information to maintain the building as well as to communicate with senior management and building owners. The Figure 4 illustrates the applications of BIM integrated CAFM in occupancy stage.

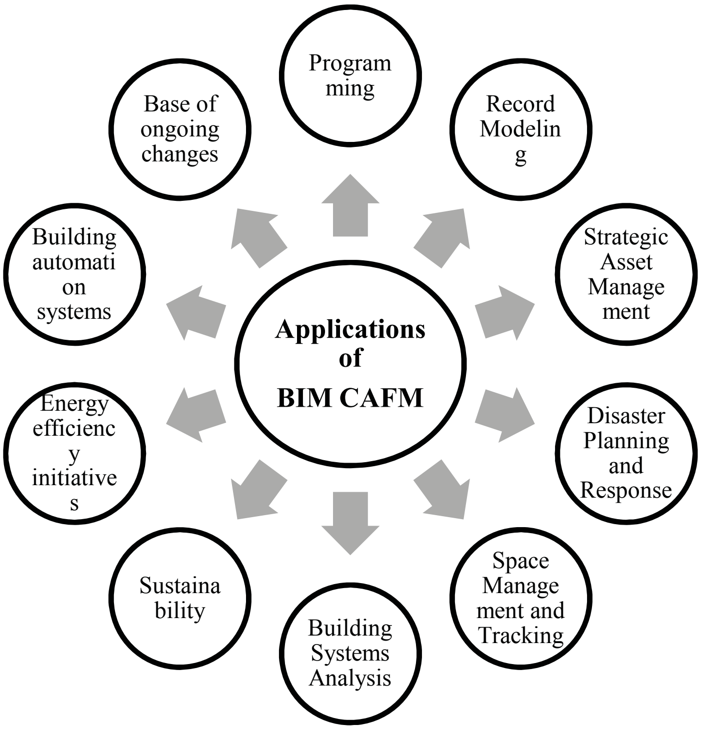

Figure 4: Applications of BIM Integrated CAFM (Source: Autodesk, 2013)

4.4. *CHALLENGES IN BIM INTEGRATION WITH CAFM*

The following challenges will be occurred when BIM integration with CAFM,

1. Challenges with collaboration and teaming with FM department
2. Legal changes to documentation ownership and production
3. Changes in practice and use of information
4. Implementation issues
5. User interference
6. Interoperability problem
7. Software hardware and liveware requirement
8. Implementation strategy
9. Technological problems
10. Poor cloud computing facilities

5. CAFM AND BIM IN SRI LANKAN CONTEXT

This research has been initiated in Sri Lanka. FM is in infancy stage in Sri Lanka. During an interview conducted on 21 January 2013, leading Facilities Manager stated that CAFM is not used in Sri Lanka, and neither does BIM (Jayasena and Weddikkara, 2012). Therefore the primary challenge for this research is that observational data will not be available for the study. This is however, not a limitation since the research does not focus on CAFM in Sri Lanka. Absence of both technologies in practice makes it difficult to collect necessary technical and human resources conduct an experimental study. Thus, the researchers will have to rely on published data. However, it was found that necessary data is not readily available in published media. The researchers will generate necessary data for the research by analysing various publications available.

6. CONCLUSIONS

The review of current knowledge shows promising integration of BIM with CAFM. COBie was found to be the primary focus in present day endeavours for this purpose. While COBie is thought to be a well-developed data exchange from BIM to FMs, it is not certain if all information demanded by CAFM is delivered by it. There were other implementations in projects using IFC (Industry Foundation Class: open BIM model) as data exchange showing significant degree of success. Thus, it could be hypothesise that BIM will satisfy the information needs of CAFM to a significant extent. However, research is required to verify this with certainty so as to how far it will satisfy the needs. Identification of this will help future advancement of BIM to become more FM friendly and CAFM application developers to consider BIM integration without reluctance.

However, the environment in which the research is being conducted is in its infant stage in terms of CAFM and BIM. This poses significant challenges in terms of applicable methodology for the study. The researchers will use various publications to generate required data. This method relies on the assumption that technology implementation documents such as white papers and user manuals represent what information is necessary for and available in each application. The conclusions made from this data will therefore be "how far BIM can theoretically satisfy the information needs of CAFM". Ultimately, the integration of BIM supported by these findings can move the FMs practices towards SFM for everlasting sustainable facility operations.

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AN EVALUATION OF THE OUTCOMES OF THE URBAN DEVELOPMENT PLANS WITH SPECIAL REFERENCE TO MORATUWA URBAN DEVELOPMENT PLAN

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ABSTRACT

Plan outcome evaluation (POE) is very significant rather than focusing on planning process, usefulness of plan, content and quality of plan. POE has been ignored in the field of planning due to lack of proper POE method.This study focuses on the ex post facto evaluation considering the outcomes of action projects of development plans and aim to develop a POE method to evaluate outcomes of development plan towards the achievement of its objectives quantitatively since no one has made such an attempt. Achieving outcomes of development plan directly affect for sustainable urbanisation. A comprehensive literature survey revealed that adaptation of the components of objective driven, theory-driven and theory-based, utilization-driven and theoretical data-driven evaluation methods will lead to overcome related issues on plan outcome evaluation and identified basic four steps suitable to incorporate in any POE method.This developed POE method comprises four steps including mathematical models. Field surveys and questionnaire surveys were carried out to identify public perception on achievement of outcomes of action projects. Developed POE method can be used as a progress monitoring tool and as an outcome evaluation tool. This POE method will be a useful tool for planners, project managers and policy makers to improve planning practices and provide necessary knowledge for revising plansin order to ensure the sustainable urbanisation. This study can be extended to evaluate the outcomes of development plan when objectives are clear and measurable further considering theory, process and objectives driven methods.

***Keywords**: Outcomes of Development Plan; POE Method; Public Perception.*

1. INTRODUCTION

The implementation of development plans and the evaluation of outcomes of plans have been ignored for decades in the field of planning (Houghton, 1997). Since the mid-1990s planning scholars have given considerable attention to define the characteristics of plan quality and to evaluate the effects of plan making practices on plan quality (Erickson *et al*, 2004, Laurian, 2010).In the late 1990's it was consideredevaluating the outcomes of planning activities, rather than focusing on planning processes (Houghton, 1997, Carmona and Sieh, 2008). Verifying planning outcomes can also contribute to the accountability and trust in, public managers and institutions, and should guide improvements in plans and practices (Kaiser *et al*, 1995). Snyder and Coglianese (2005) show that the positive outcomes are becoming appropriately relevant and the post facto evaluation of plan outcomes should become an essential part of the planning practice. And also outcome evaluation is the true test of managing effectiveness (Hoch, 2002)

Impacts of action projects are the outcomes of development plans, which are to be contributed to the development impact of the planning region (Bagwat and Sharma, 2007).They are accountable for achieving objectives of development plan and contributing to the development impact (Morrison and Pearce, 2000). As Carmona (2007) argues a final analysis of the outcome of development plan in any

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one place of development processes over time, it can only be made when the actual outcomes from the process itself is being evaluated. Laurian *et al.* (2010) introduces conformance-based evaluation which assume observable causal linkages between planning goals, activities and outcomes and require clearly defined goals and objectives which can be measurable with measurable indicators and logically derived planning strategies. But in practice, these evaluations are complicated because plan objectives are not always clear and measurable and multiple strategies are used to advance objectives (Seasons, 2003, Snyderand Coglianese, 2005). Outcomes also are not necessarily measurable and it is extremely difficult to attribute observed outcomes to plans(Carmona and Sieh, 2008).Since there is no proper POE method,planners cannot know whether plans achieve their objectives, or learn from the results of past interventions to improve planning practice (Baehler, 2003, Seasons, 2003). Therefore this study is supposed to develop and test a POE method as main objectives of the study. This POE method will be a useful tool to planners, project managers and academics seeking to assess the outcomes of plans in local level. The other objectives supposed to be fulfilled while carrying out this study are identifying the importance and progress of planning evaluation, types of outcome evaluation, past applied POE methodologies and related limitations and weakness on them. Then it was identified suitable elements, basic steps and proposals to be taken into account when developing proposed POE method.

2. PLANNING EVALUATION

Planning is the process of analysing information, making decisions and formulating plans of action for future. Planning can be undertaken by government in many sectors with appropriate methodologies, and techniques to achieve relevant goals and objectives (Glasson, 1982, Brutonand Nicholson, 1987). Development plan will provide the spatial framework for promoting and regulating the physical development of lands and buildings in each of the urban area to ensure the sustainable urbanisation (Bruton and Nicholson, 1985). Patton (1989) and Michael (2002) states that planning evaluation is the systematic assessment of plans, planning processes, and outcomes compared with explicit standards or indicators and itis important since it ensures accountability,improvement and knowledge of the development plan. Berke (2006) states three types of planning evaluations as process, impact and outcome evaluations. Planning evaluation can be conducted for different purposes as a priori or ex ante evaluation (Alexander, 2006), on-going monitoring or formative evaluation (Scriven, 1967) and ex post facto or retrospective evaluation (Baum, 2001, Snyder and Coglianese, 2005).The literature on the ex post facto evaluation of planning outcomes is underdeveloped and actual outcome evaluations by practitioners are rare (Carmona, 2007, Carmona and Sieh, 2008).

2.1. BASIC ELEMENTS

Evaluating the outcome of planning activities is very significant rather than focusing on planning process, usefulness of plan, content and quality of plan (Baer, 1997).There is less significance on evaluating outputs and impacts of plan. Evaluate planning outputsis evaluating policies, programmes, projects and regulations rather than outcomes (Baum, 2001).Impacts of the plancan be evaluated considering benefits in terms of implementing in strategies, actions, rules, regulations, policies, structure and systems (Berke *et al*, 2006 and Corol,1998). In rational perspective, it assumes that plan goals and objectives translate into policies and methods, which are implemented to address specific problems and yield expected outcomes. This is how legislation and planning mandates tend to be designed and how planners usually conceptualize their practice (Berke *et al*, 2006 and Laurian *et al*, 2010).

More recently, Carmona and Sieh (2008) investigates outcome assessments in planning, and best practices in performance evaluation. They show that the performance indicators have been used focused on development controls, and on the speed of the permitting process, which measures the outcome focusing mainly on user satisfaction. These studies are based on sophisticated analysis, but do not establish whether the outcomes observed are caused by planning activities or external factors. Mayne (2001) states that evaluation of strategies is best suited to evaluate the outcomes of local plan elements. It can be concluded that objectives of the plan, implementation of activities and outcomes of planning activities should be considered as basic three elements of any POE method (Houghton, 1997, Laurian *et al,* 2010).Conformance-based evaluation method requires that plan objectives be clear and measurable with measurable indicators, but practically objectives are not always clear and measurable. Therefore proposed POE method should not be responsive to application of conformance-based evaluation method. Performance-based evaluation is well suited to evaluate comprehensive and strategic plans, seen as broad efforts to identify, formulate, and promote main vision and goals (Mastop and Faludi, 1997).

2.2. TYPES OF OUTCOME EVALUATION

The policy and programme evaluation literature identify three types of outcome evaluations by providing their limitations and weaknesses. Laurian *et al,* (2010) have added a fourth pragmatic category, called as theoretical data-driven evaluation. First, objective-driven evaluation focuses on whether the programme goals and objectives are achieved (Baer, 1997, Weiss, 1997). Most have been attempted to evaluate plans by adopting this approach (Berke *et al,* 2006, Laurian *et al,* 2010, Talen, 1997, Weiss, 1997). Second, theory-driven evaluation seeks to clarify the relationship between the plan and the outcome (Berke, 2006, Weiss, 1997). Theory-driven evaluation is used infrequently and has been criticized as 'esoteric' (Patton, 1989) and 'having only marginal influence on evaluation practice' (Weiss, 1997).The third form of evaluation was proposed by Patton (1997) in response to the practical inapplicability of theory-driven evaluation. This is utilization or stakeholder focused evaluation. Fourth, theoretical data-driven evaluation is designed to track changes over time because planners often evaluate plan impacts using available data and indicators. The proposed POE method should be built on components of objective driven evaluation, theory-driven and theory-based evaluation, utilization-driven evaluation and theoretical data-driven evaluation. The combination of components for all these four types of outcome evaluation will lead to overcome the main barriers of POE.

2.3. BARRIERS FOR EVALUATING PLAN OUTCOMES

Plan outcomes are rarely evaluated by planning agencies (Carmona and Sieh, 2008, Seasons, 2003).This gap can be explained by several factors. First, evaluation requires selecting indicators of success and obtaining relevant data and information (Baum, 2001, Snyder and Coglianese, 2005).

Incompatible goals need to be reinterpreted by evaluators to select evaluation criteria and indicators (Seasons, 2003). In addition, evaluators must choose which intended and unintended outcomes to assess (Hoch, 2002, Snyder and Coglianese, 2005).

Monitoring and evaluation also require appropriate and reliable data to identify trends and changes of the plan implementation (Baehler, 2003, Seasons, 2003). Yet, very few plans are provided for monitoring processes to evaluate the effects of land-use decisions, or identify discriminating indicators suitable for linking plan objectives to measurable outcomes, especially in the area of spatial planning (Snyder and Coglianese, 2005). Thus, evaluators often rely on proxy variables, which are often too removed from planning decisions to talk much about their outcomes (Baum, 2001). Secondly, evaluation also assumes that weaknesses should be identified to promote change, but more organizations and administrators reluctantly can resist evaluations they perceive as threatening (Baehler, 2003). Even if committed, many planning agencies, and especially local authorities, often lack of resources in time, staff, or expertise to support plan monitoring or evaluation (Baehler, 2003, Seasons, 2003).

Third, evaluating plan outcomes is methodologically difficult. Existing evaluation methods are generally not designed to address the physical, environmental, and spatial components of planning.The main difficulty faced by evaluators is the lack of a generally accepted ex post facto planning outcome evaluation methodology (Baehler, 2003, Talen, 1997). The most problematic methodological question is the attribution, or causality, question. It is difficult to distinguish the outcomes of planning activities from other factors (Carmona and Sieh, 2008). Evaluation assumes the ability to track the outcomes of an intervention with full information, and without ambiguity (Baum, 2001). Finally identifying a cause relationship between planning decisions and outcomes is difficult (Baum, 2001, Seasons, 2003). Talen (1997) argued that "explanatory chains linking objectives and outcomes are virtually unattainable" but that "associations between plans and outcomes or between intended objectives and actual implementation can be ascertained". Eventhough, there are more barriers for evaluating outcomes, two POE methodologies have been developed by Mayne (2001) and Laurian *et al,* (2010) to evaluate the outcomes of plan under certain circumstances of related problems.

3. DIFFERENT POE METHODOLOGIES AND RELATED PROBLEMS

Mayne (2001) has proposed a pragmatic contribution analysis based on `believable association' by: (1) acknowledging the attribution problem (2) identifying the logic of the plan (3) describing the expected behavioral changes of the target population (4) using discriminating indicators (5) tracking performance over time to establish the co variation of plan and outcomes (6) exploring exogenous explanations for the outcomes and (7) triangulating evidence from expert opinion, case studies, and other sources to confirm the findings. In other words, a pragmatic approach of evaluation relying on expert knowledge and multiple sources is the only method proposed so far to address the attribution question.

Laurian *et al,* (2010) presented an innovative POE methodology developed in New Zealand, where localities are required to monitor the effectiveness of their plan policies, methods and regulations. This ex post facto POE approach is practical, reflexive, and hybrid. It combines evaluation strategies best suited to evaluate the outcomes of local plan elements (Davidson, 2000, Hoch, 2002, and Mayne, 2001). It does not assess the impacts of strategic plans overall, but rather the specific outcomes of discrete plan elements with specific goals and objectives. It seeks to answer these questions: Are plan objectives achieved? Why or why not? Are observed outcomes attributable to the plan? This methodology builds on theory-based and objective-driven evaluation components. It (1) develops and builds on a conceptual model of plan logic and implementation (2) investigates associations between plan goals and outcomes and (3) uses structured expert assessments to identify causal relationships between plan provisions and outcomes.

These two methodologies laid a foundation by deriving basic four steps that should be included in proposed POE method. They are:

- Identify logical sequence and coherence of plan elements (Theory-based evaluation and theory driven evaluation)
- Identify the associations between objectives and outcomes (Objective-driven evaluation)
- Measure the outcomes using data from samples of observations (Utilization driven evaluation)
- Obtain an overall assessment(Theoretical and data driven evaluation)

These methods facilitated to estimate whether planning interventions and changes contributed to achieve expected outcomes in yield weak, moderate, or strong positive or negative and obtain an overall assessment qualitatively. There is no quantitative method to evaluate the outcomes of plan towards the achievement of its objectives. In order to overcome the problems associated with current POE methodologies, the proposed POE method should not be sensitive for Conformance based approach and Performance based approach. When implementation is poor, attempts to link outcomes to plans become meaningless (Laurian *et al,* 2010). Even though, the proposed POE method should be sensitive to evaluate the outcomes of poor or not implemented activities as well. Then the proposed POE method will be more effective in a case of evaluating the outcome of any development plan.

3.1. PROPOSALS TO OVERCOME THE ISSUES

Identifying relationship between objectives and outcomes of plan is required since outcomes are the results that link to the immediate objectives as described in the development plan (Bagwat and Sharma, 2007). Berke (2006) shows that stakeholders should be get involved in the process of evaluating the outcome of plan. Reviewing public perception is a good technique to study the present situation and evaluate the outcomes of plan (Marques *et al,* 2010, Baum, 2001, Seasons, 2003).

Fourth, Planners must be aware of the factors that affect stakeholder participation (Burby, 2003) because planners' failure to recognize the differences in evaluation between experts and public may lead to figurative protests (Norton, 2008). According to the Section 8D of UDA Act of No: 4 of 1982, public are being consulted only during post preparation of development plan and that should be done for plan evaluation. Local authorities' responsibility is to get involve people in both planning and implementing activities (Circular No 01 under reference 08/01/38 dated on 20/03/1985).

3.2. APPLICATION OF PLANNING, QUANTITATIVE AND STATISTICAL TECHNIQUES

Reviewing public perception is one of the techniques which can be applied to study the present situation, and to evaluate the outcomes of projects, since it has being benefited greatly throughout the past practices (Berke, 2006), Seasons, 2003, Marques *et al,* 2010). Objective achievement matrix is another advance planning technique which has been applied to identify the relationship between objectives, proposed strategies and action projects (Lichfield, 1996, Sager, 2003). This technique is applied to develop the first step of proposed POE method. Field surveys and questionnaire surveys were selected as the data collection technique, since they will be supported for reviewing public perception on the outcomes of action projects of Moratuwa development plan. Accordingly 100 people who live in Moratuwa MC Area, 20 project officers who have been involved in eachproject and 05 planning officers of Moratuwa MC were selected randomly, for a125 sample size. In this study, the researcher cannot control the independent variables (Kraemer, 2002) that are occurred as outcomes of the development plan itself. Therefore, experiment is not applicable for this study. That is why field surveys andquestionnaire surveys were carried out as suitable techniques to investigate the outcomes of all action projects of Moratuwa development Plan.

4. POE METHOD AND ITS APPLICATION TO MORATUWA URBAN DEVELOPMENT PLAN

The developed POE method is suitable to apply in planning industry for effective management of plan implementation, evaluation of outcomes of planning activities (action projects), and to overcome the issues pertaining to the evaluating of outcomes of development planwhile ensuring sustainable urbanisation. The author has developed this POE method by presenting four basic steps which comprise mathematical models and methodological descriptions. They are:

- Step One - Identify the logical sequence and coherence of plan elements (Theory-based and theory driven evaluation)
- Step Two - Identify the associations between objectives and outcomes (Objective-driven evaluation)
- Step Three - Measure the outcomes of action projects (Utilization driven evaluation)
- Step Four - Calculate Overall assessment Value (Theoretical and data driven evaluation)

Moratuwa urban development plan has been constituted in 2004 under Section 8F of the Urban Development Authority Act No.4 of 1982 with an intension to implement main six action projects by year 2014. Out of those projects, three action projects have been implemented successfully (which are highlighted in Table 3) while other three action projects are being implemented. Application of objective achievement matrix under step one of above POE method emphasized that three action projects are directly related to achieve specific objective separately while other three links to achieve two or three objectives together (refer first two columns of Table 3).

As an application of objective-driven evaluation method, under the step two it was identified relevant criteria of objectives (C_j) where 'j' is the number of criteria of relevant objectives. Accordingly each action projects directly related to achieve main three elements of objectives (refer third column of table3). Activities of each action projects (A_i) where 'i' is the number of activities of each action project (i = 1, 2, 3…n), their progress and the implementation level were identified under the same step (refer first three columns of Table 2). The level of implementation of each activity was evaluated giving a percentage value, as 1 for totally implemented activity, 0.75, 0.50, 0.25 for partly implemented activity and 0 for not implemented activity. Not implemented activities were not evaluated. These values are calculated specially, based on the perception of planning officers and project officers rather than considering perception of communitywho are not much aware about the level of implementation. The actual level of implementation of each activity was got clarified considering the confirmation of planning officers of Moratuwa Municipal Council. This proposed POE method will be more effective in a case of evaluation the outcome of any development plan since this method is more applicable for partly implemented development plan as well. And also this will become meaning full for meeting even non measurable objectives as well.

Under step three, Outcomes of action projects were evaluated considering the impact level of each activity of each action project. This was done using data from samples of questionnaire surveys which issued for planning officers, project officers and community. This step totally depends on utilization driven evaluation by calculating percentage of respondents for each activity against each criteria and impact level. It is required to consider intensity of the contribution of each activity of each action project to achieve the identified each criteria of relevant objectives. Since all identified action projects are positively contribute to achieve relevant objectives of development plan, Assume that there will not be a situation which has no impacts and negative impacts of action projects and related activities, hence the zero value and negative values are not considered. Intensity of the contribution of each activity is evaluated considering the impact level as low (1), moderate (3) and high (5) by applying 1,3,5 likert scale (Brown, 2011) to give weightage for each impact level. When there is low impact level, scale is given as 1 and it is three times as higher for moderate level (3) and five times as higher for high level (5).

In order to have an overall assessment value for the evaluation of outcomes of development plan, step four was developed including mathematical models such as multiplication model and Additive models. Activity vs Criteria values (A_iC_j) were calculated to indicate the intensity of the contribution of outcome of each activity of each action project against criteria of related objectives. $\sum A_iC_j$ values are calculated by applying "Weighted Scoring method". The percentage values of respondents against each impact level under each criteria of objectives were multiplied by related percentage of implementation level of activity and weight of the impact level to find A_iC_j value for each activity under particular criteria. Then all A_iC_j values under each activity against relevant objective criteria were added to the $\sum A_iC_j$values for those relevant criteria separately.

$$\text{Total Activity Vs Criteria Value} = \sum_{i=1}^{n} A_i C_j$$

Finally, Criteria Achievement Values (CAV_j) was derived by considering the maximum level of contribution of all activities to achieve the identified each criteria of relevant objectives. This value indicates the contribution level of outcome of each action project towards the achievement of criteria of related objectives.

$$\text{Criteria Achievement Values } (CAV_j) = \frac{\sum_{i=1}^{n} A_i C_i}{5n}$$

This value interprets the strength of the intensity of contribution of outcomes of action project towards the achievement of related criteria of objectives. This can be proposed in the presentation format indicating in Table 1 for the easiest of understandable.

Table 1: Achievement Level of Objective Criteria

Criteria Achievement Values (CAV_j)	Achievement Level
0 .01% - 20.00%	Very Low
20.01% - 40.00%	Low
40.01% - 60.00%	Moderate
60.01% - 80.00%	High
80.01% - 100.00%	Very High

Table 2: Calculating ($\sum A_iC_1$) and CAV_j Values for Lunawa Housing Development Project

Implemented activities under Housing Development Project (A_i)	Implemented or Not	Level of Implementation %	Criteria of the Objectives (C_j)											
			C_1.To Improve standard of living				C_2.To provide better quality houses				C_3.Provide infrastructure facilities			
			Impact Level				Impact Level				Impact Level			
			Low	Moderate	High	**A_iC_1**	Low	Moderate	High	**A_iC_2**	Low	Moderate	High	**A_iC_3**
	Y/N		1	3	5		1	3	5		1	3	5	
1.Developing hospital land by removing single storied buildings	Yes	1.00	0.70	0.20	0.10	1.80	0.40	0.30	0.30	2.80	0.80	0.20	0.00	1.40
2.Constrcuting required number of houses for low income families	Yes	1.00	0.20	0.20	0.60	3.80	0.10	0.50	0.40	3.60	0.20	0.70	0.10	2.80
3.Constrcuting outdoor dispensary	Yes	1.00	0.20	0.20	0.60	3.80	0.80	0.20	0.00	1.40	0.60	0.30	0.10	2.00
4.Upgrading Road condition	Yes	1.00	0.50	0.10	0.40	2.80	0.70	0.10	0.20	2.00	0.40	0.30	0.40	3.30
5.Provide common facilities (compound, park, drains)	Yes	0.75	0.60	0.20	0.20	1.65	0.80	0.20	0.00	1.05	0.80	0.10	0.10	1.20
6.Provide water supply to all house holds	Yes	1.00	0.10	0.10	0.80	4.40	0.00	0.20	0.80	4.60	0.10	0.30	0.60	4.00
7.Provide electricity for all house holds	Yes	1.00	0.00	0.20	0.80	4.60	0.00	0.30	0.70	4.40	0.00	0.10	0.90	4.80
Total Activity vs Criteria value ($\sum A_iC_j$)						22.85				19.85				19.50
Criteria Achievement Value- $CAV_j=(\sum A_iC_j/5n)$			65.29%		High		56.71%		Moderate		55.71%		Moderate	

Table 3: Calculating ($\sum A_i C_1$) and CAV_j Values for All Six Action Projects

Action Projects	Objectives	Related Criteria of the objectives (C_j)	Criteria Achievement Value CAV_j	Achievement Level
1. Town Center Development Project	1. Development as a waterfront city	C1-City development C2-water front city	40.00% 35.80%	Low Low
	2. Improve the infrastructure facilities	C3-Improve infrastructure facilities	43.80%	Moderate
2. Katubedda Sub-Town Development project	2. Improve the infrastructure facilities	C1-Improve infrastructure facilities	26.00%	Low
	3. Provision of facilities to improve the industries in the town	C2-Provide facilities to improve industries	18.20%	Very Low
	4. Improvement of the fishing industry	C3-Improve fishing industry	23.20%	Low
3. Lunawa Lagoon Development Project	5. To protect natural resources, and maintain the development of the town and its environmental equilibrium	C1-to Protect natural resource C2-to maintain City development C3-for Ecological Balance	58.57% 59.00% 40.57%	Moderate Moderate Moderate
4. Lunawa Housing development project	6. Improve the standards of living by providing housing and infrastructure facilities for low income settlements in the town	C1-to Improve standard of living C2-to provide better quality houses C3-Provide infrastructure facilities	65.29% 56.71% 55.71%	High Moderate Moderate
5. Coastal Road Development Project	7. Establishment of an efficient transport system	C1-to establish efficient transport system	32.40%	Low
	8. Maintenance of reservations of public roads and waterways	C2-to maintain reservation of public roads C3-to maintain reservation of water ways	36.20% 37.40%	Low Low
6. Parks Development Project	9. Establishment of adequate number of parks, playgrounds and open spaces	C1-Provision urban recreational facilities C2-Optimum utilization of Urban land C3-Provide open space	49.43% 54.71% 50.86%	Moderate Moderate Moderate

When CAV_j indicates 100%, the idea is all activities of the action project have been implemented 100% by delivering all expected outcomes to achieve anticipated criteria of related objectives. Less than 100% of CAV_j values indicate that either activities of related action project have not been fully implemented or impacts have not fully achieved through anticipated outcomes or both. Calculating ($\sum A_iC_1$) and CAV_j values for Lunawahousing development project as a one action project out of six of Moratuwa development plan (Table 2) and the $\sum A_iC_1$) and CAV_j values for all six projects (Table 3) can be shown as follows.

5. CONCLUSIONS

According to the results of the application of POE method, outcomes of all three implemented action projects have been contributed to achieve relevant criteria of objectives in moderate level by indicating CAV_j values in between 41% to 65% .Other partly implemented three action projects have been contributed to achieve related criteria of objectives in low level by indicating CAV_j values in between 18% to 40%. It was suggested that this developed POE method was applied as a tested method to evaluate the outcomes of development plan and should be updated according to the dynamic nature of the planning industry.

5.1. LIMITATIONS

Outcomes of Moratuwa urban development plan were evaluated towards the achievement of its objectives considering the impact level of all identified action projects only. This case study reflects the stakeholders' satisfaction on the outcomes of action projects but has not done a study about the planning process and theories which were applied to identify strategic action projects of selected urban development plan. The level of implementation of each activity of each action project was evaluated considering perception of planning and project officers only. The impact level of each activity to achieve related criteria of objectives were evaluated as low, moderate and high by giving assumed weightage values of 1, 3 and 5 consequently. Since criteria of objectives are ambiguous, it was needed to explain them to participants. This method should avoid selecting only stakeholders who will positively evaluate the plan's outcomes. There can be long time lags between plan adoption, implementation, project outcomes and development impacts. Therefore, this evaluation method is developed based on detailed information about project implementation, project outcomes andprimary data which were collected through field observation and questionnaire survey.

5.2. CONTRIBUTION TO KNOWLEDGE

This developed POE method will be a useful tool to planners, project managers and academics seeking to assess the outcomes of plans and as a progress measuring tool in local level.Because Criteria Achievement Value (CAV_j) indicate the intensity of contribution of the action project to achieve related criteria (C_j) of its relevant objectives considering outcomes of all implemented and not implemented activities. Results of the application of POE method and past interventions facilitate to learn and improve planning practice, while providing the necessary knowledge to revise plans, improve performance of action projects, and increase the transparency and accountability of planning practice. The process of application of this POE method involves all relevant stakeholders to evaluate the outcomes of plan. Then community will identify how the plans have shaped up their communities and they will help the planners, project managers and the politicians to achieve the expected outcomes.

5.3. FURTHER RESEARCH

This POE method can be further modified with the factors suggested by the professionals and developed into a mandatory check list. The quality of the POE method can be enhanced by incorporating evaluation aspects of planning process, and theories which were applied to identify strategic action projects of selected urban development plan when objectives and outcomes are measurable (Laurian, 2010).The effectiveness of this POE method in Sri Lankan planning industry should be tested with a few more implemented development plans.

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APPLICABILITY OF SOCIO-ECONOMIC FACTORS IN SUSTAINABLE CONSTRUCTION FOR SRI LANKAN CONTEXT

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ABSTRACT

"Sustainability" has emerged as a vibrant field of research and innovation over last few decades. The concept is based on three basic factors; environment, social and economic, namely the Triple Bottom Line. Frequently, the environmental aspect, despite the social and economic aspects, is given a major emphasis in the global arena of sustainable construction. The World Green Building Council (WGBC), being the leading institute in sustainability, has initiated the first step towards assessing the socio economic factors in the field of sustainable construction, which are being neglected in rating green buildings due to its immeasurability as a tool, by developing a framework for assessing the concerns addressed in the Triple Bottom Line. The WGBC criteria presented in seven sections hold concepts developed by the expert panel representing 14 countries, for assessing the social and economic factors. Since the concepts are in contrast with Sri Lankan context, they seek readjustment in order to match Sri Lankan context. Research agenda hascommenced with a comprehensive literature survey, followed by expert interviews and a questionnaire survey. The process of developing the theoretical framework to determine the appropriate weightages between each rating has proceeded using the indicators and benchmarks of the available frameworks. Adjusted criteria of the social and economic factors would be able to improve the applicability of GreenSL to assess the green buildings in Sri Lanka. Developed framework through the evaluation process in the research would be capable of assessing the Sri Lankan sustainable constructions in a more appropriate manner, with proper compositional integration of socio-economic and environment factors. A comprehensive assessment of sustainable construction could be achieved through the developedtheoretical framework that is fitted in to the Sri Lankan context with due consideration on aspects addressed in Triple Bottom Line; economic, social and environment.

Keywords: *Construction Delays; Delay Analysis Techniques (DAT); Utility Factors.*

1. THE CONCEPT OF SUSTAINABILITY

The concept of Sustainability evolved in comparison and contrast with resource availability, defined by various authors in different disciplines since its inception. Roper & Beard, (2006) describe sustainability on a basis of duo facts: having the awareness of the fragility of living things, their ecosystems and the resources on which they depend; and about seeking to implement technical and economic efficiency with a soul and a conscience. Ott, 2003, (cited in Smith, 2011) asserts in his work that sustainability is referred to a system, in which the economy is a subsystem of human society; meantime, holistically being a subsystem of the biosphere, and a gain in one sector may result in a loss in another sector.

According to the literature by (Chabowski *et al.,* 2011), sustainability accounts a direct relationship with corporate social responsibility (CSR), cause-related marketing, corporate citizenship, enviropreneurial marketing, and corporate environmentalism (cited in Mysen, 2012). Filho(2000) points out the misconceptions in the concept of sustainability in terms of its scope being too broad, non-availability of a specific institution to deal with it, demanding substantial resources which do not stand in myriads or justifiable, and lacking the scientific base as proved by his sample survey.

The direct relationship sustainability demonstrates with resources, which is scarce in nature and requires precise use so as not to compromise future use, has increased the conceptual validity over

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time, and has resulted in rapid development of the concept though it comprises both merits and demerits. Sustainability is the major influential concept towards mankind, guiding the human activities ensuring the resource availability for upcoming generations. Two basic approaches are discussed in sustainability, "top down" and "inside out". Top down approach emphasizes on management, measurement and control while inside out emphasizes on change and innovation (Henriques & Richeardson, 2004).

2. THE CONCEPT OF TRIPLE BOTTOM LINE

According to (Jamali, 2006) the Triple Bottom Line concept was put forth to the center concern with the rise of the need of sustainability improvements in organizations. The Earth Summit of Rio in 1992, gave rise to the concept of sustainability and accordingly the concept of Triple Bottom Line came in to light in relevance with sustainability. Triple bottom line simply adhere to three basic terms, environment, social and economic; in other words planet, people and profits (Swanson & Zhang, 2012) which express direct impacts on sustainability. Aforesaid three areas are also integrated, accounting the contributory dimensions of sustainability as a concept itself.

Environmental dimension addresses organizational impacts on living and non-living natural creatures including land, air, water and eco systems. It adheres to the compliance with the government regulations and same time the initiatives on energy efficiency or recycling. Social dimension addresses the impacts of organization towards the society which it operates, emphasizing basically on public health, community issues, publiccontroversies, skills and education, social justice etc. Economical dimension refers to the financial strength or activities of the organization in the market. This will run through issues of competitiveness, job and market creation and long-term profitability (Jamali, 2006).

3. RELATIONSHIP OF TBL WITH THE CONSTRUCTION INDUSTRY

The mutual relationship between the Triple Bottom Line and the construction industry can be primarily defined as sustainable construction. This implies the need of complying built environment with the basic rules of Sustainability in terms of Environmental, Social and Economic. Dickie and Howard (cited in Pitt, Tucker, Reily & Longden, 2009) claimed sustainable construction as to what is built today should be capable of accommodating future, same time, being influential to meet the need of future generations. The importance of Sustainable construction is surged with the presence of managerial tools and methodologies to improve the performance of the construction industry (Persley & Meade, 2010).

Sustainable construction has enlighten thetriple-bottom line in consideration of following objectives according to Department of the Environment, Transport and the Regions, London (DETR) (cited in Persley & Meade, 2010):

- More profitable and more competitive;
- Enhancing and protecting environment;
- Treating the stakeholders in fruitful manner;
- Provide built environment which is with satisfaction, well-being and value to customers and users; and
- Minimizing the impact on the consumption of energy and natural resources.

Few barriers are identified in the adoption of sustainable measures to the construction industry, such as; negligence of sustainable measures by the stakeholders, restrictions for sustainability measures by regulatory bodies, minimization of particular site advantages with the use of sustainable measures and inability of using sustainable measures locally due to lack of knowledge, expertise and technology etc. (Williams & Dair, 2006)

4. Relative Importance of Social and Economic Factors in Construction

The current trend of construction ratings had been emphasizing on the environment aspect, with less or no due consideration on social and economic aspects. The well-established rating tools with regard to the environment aspect have created a sound basis in terms of environmental protection and resource efficiency, making forth a limited space for assessing social and economic factors – which do account as significant parameters directly involved in sustainability agenda (Akadiri and Olomolaiye, 2012).

The leading rating systems of green buildings like Leadership in Energy and Environmental Design (LEED), Building Research Establishment's Environmental Assessment Method (BREEAM), Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) have considered relevancy, measurability, applicability and availability as influential factors of energy efficiency and environmental concerns (Fowler & Rauch, 2006), in which the immeasurable, mostly qualitative aspects of socio-economic component remain unconsidered. At the stage of commencement of ratings, the measurement is said to be the dollar value.

The present day practices of developing future scenarios in sustainable development dealing with successful environmental sustainable strategies, the social and economic dimensions are being neglected. There should be either equal footings for the all three contributory factors of sustainable frameworks; environment, social and economic, or there should be a proper trade-off between aforesaid tri-factors. Established standard rating systems are said to be failed in the basis of application efforts in to different categories of society (Omann & Spangenberg, 2002)

5. Review of Social and Economic Factors in Available Rating Systems

The concerns on social and economic factors in available rating systems are noticeably low in comparison with environmental aspect. LEED and BREEAM rating systems concern on indoor environmental quality which relates with the productivity of employees with healthy working life (Persley& Meade, 2010).

BREEAM is known as the worlds' first commercially available and mostly used assessment criteria and LEED is regarded as the worlds' mostly established rating system strictly limited to environmental assessment methods with less or no consideration on socio-economic aspects, in which environmental protection and resource efficiency become the centerpiece in agenda.(Akadiri and Olomolaiye, 2012).

BREEAM rating system make scores on building energy, transport, water, materials, land use and ecology, pollution, building management, occupant wellbeing and health in the assessment of the buildings (Swayer, Weilde & Brooks,2008). Although this system do account on social concerns, in a holistic view, the socio-economic factors are not properly trade-off as per the weights assigned in the sustainability frameworks. CASBEE, the Japanese rating system too showcases less concern on so called immeasurable social and economic factors; instead, their emphasis is on energy, water, land usage, materials and measurable indoor environmental aspects (Potbhare, Syal, Arif, Khalfan & Egbu, 2009).

According to the LEED 2009 for new constructions and major renovations project checklist, it is required to assess the facility under the sustainable sites (concerning the site facilities), water efficiency (usage of water), energy and atmosphere (concerning energy efficiency), material and resources (selection and usage of materials for construction), indoor environmental quality (health and wellbeing of the occupants within the built environment) and innovation and design process. Similar to most of the available rating systems, this too lacks due consideration on social and economic aspects.

6. THE FUTURE OF EVOLUTION OF THE SOCIO ECONOMIC CONCERNS IN SUSTAINABLE CONSTRUCTION

The International body for rating green buildings, World Green Building Council (World GBC) has realized the importance of considering the social and economic aspects in rating green buildings or sustainable constructions. This is identified as a major deficiency prevailing in the current practices of ratings.

WGBC initiated in introducing a new social and economic criterion as a new assessment tool for rating systems. The World GBC criteria for assessing the social and economic factors are presented in seven sections holding concepts developed by the expert panel representing 14 countries. Those seven sections comprise with;

- Employment creation
- Economic opportunity
- Training and skills development
- Community benefits
- Mixed income housing
- Equity and;
- Health and safety

Aforesaid framework provides a better guidance for assessing the sustainable construction precisely adhering to the Triple Bottom Line concept; integrating environment, social and economic factors.

7. CONSIDERATION OF SOCIAL AND ECONOMIC FACTORS WITH AVAILABLE ASSESSMENT CRITERIONS

This section would examine the consistency of the social and economic factors drafted by the World Green Building Council with the participation of international experts in sustainable constructions, in relation to a series of well-known existing assessment criterions; LEED, BREEAM, GREENSL and the South African rating system.

The rationale behind selecting specifically above criterions is that, LEED is regarded as the world's mostly established rating system, while BREEAM is considered as world's first commercially available and mostly used assessment criteria. Being the Sri Lankan rating system, GREENSL inevitably adds up to the account, and finally, the most important South African rating system was selected due being the proud pioneers and inculcators of indicating Social and Economic factors in to assessment of sustainable construction.

Table 1: Comparison of Social and Economic Factors with Existing Assessment Criterions

Factors Considering	**LEED** (USA)	**BREEAM** (United Kingdom)	**GREEN^{SL}** (Sri Lanka)	**Green Star SA** (South Africa)
Employment creation Create employment through design decisions and construction practices which include labour-intensive construction methodologies	✓	✗	✗	✗
Economic Opportunity Growth and development enterprises through procurement of goods and services and enterprise development programmes	✓	✓	✓	✓
Training and Skills Development Training and skills development of employees in unskilled, semi-skilled, supervisory, technical and professional who are part of design and construction project	✗	✗	✗	✗
Community Benefit Provide community facilities responding to the current socio-economic needs and issues of identified communities	✗	✗	✗	✗
Mixed Income Housing Integrate mixed income housing with residential developments	✗	✗	✗	✗
Equity The project participants are embracing transformation and performing well in Broad Based Black Economic Empowerment	✗	✗	✗	✗
Health and Safety Health and safety practices, culture and understanding in the construction industry	✓	✓	✓	✓

8. DEMAND FOR LOCAL BENCHMARK WITH SELECTED SOCIAL AND ECONOMIC ASPECTS

Sri Lankan context of sustainable construction was enriched with a new chapter with the inception of new green building rating system in year 2011, GREEN^{SL}. This system would have similarities with existing well-established rating tools such as LEED, BREEAM, CASBEE, etc. but with more emphasis on particularly the local context and conditions in terms of assessment of buildings.

Similar to other rating systems, GREENSL, Sri Lankan Green Building assessment criteria which developed by Green Building Council of Sri Lanka do concern on major sections such as sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality and innovation and design process; in contrast GREENSL also comprises with the sections called management and social and cultural awareness which particularly deals with local conditions in assessing sustainable construction.(Green Building Council Sri Lanka, 2011). This section is further divided in to three sub sections; archeological sites and buildings, (as prerequisites) social wellbeing, and public health, safety and cultural identity. Although the initiation of considering the socio-economic factors is to be appreciated, only four points are allocated for the social and cultural awareness section which is meant to assess the social and economic aspects of the Triple Bottom Line concept. A balanced weightage between environmental, social and economic factors is required to achieve a comprehensive and sophisticated rating system for assessing the built environment.

Therefore, the adaptation of global criteria requires readjustments in order to suit the Sri Lankan conditions. Direct adaptation of Framework developed by the World Green Building Council, to the Sri Lankan context could encounter certain drawbacks; therefore, the need of a revised framework which is capable of rating Sri Lankan constructions in terms of sustainability is emphasized. Accordingly, in adapting the global criteria, local benchmarks much focused on local industry should be developed so as to harness the maximum potential benefits.

9. DISCUSSION

The paper, explores the concept of sustainability and the dual-factors essential in evaluating sustainable construction, yet not being paid due attention in comparison with mostly emphasized environment factor; social and economic. Apparently, requirement of further review on following three basic concepts has risen; weighting of factors in triple bottom line, tradeoff between consideration of social and economic factors in developing and developed countries, and the need of local benchmarking for sustainable constructions in terms of social and economic aspects, providing an analytical framework for discussion.

The very first concept, weighting of factors in the Triple Bottom Line, basically structures around the main three elements discussed in the TBL; Environment, Social and Economic which are generally applied in evaluating the sustainable construction. Thus, the major emphasis among three, tend to be on the environment aspect, rather than the remaining governing factors of social and economic. The quality of measurability and availability of qualified professionals for developing and assessing the built environment, in compliance with existing environmental parameters have resulted in an obvious negligence of social and economic factors in assessing sustainable construction in the construction industry. This gives rise to the need of paying increased attention on social and economic factors, triggering a proper composition between three factors in TBL, ultimately achieving a sound sustainability assessment. The weightings could be differed based on the location and the facility, yet, the importance of employing all three factors discussed in Triple Bottom Line; the basis of a comprehensive sustainability assessment should not be underestimated.

The second concept of discussion, trade off between consideration of social and economic factors in developing and developed countries lies on differentiating the utilization of three factors of TBL by developing countries and developed countries. Since the developed countries are capable of using advanced technologies and methodologies, the increased discharges to the environment which could be more harmful and threatening than discharges of less advanced technological users; the developing countries, the emphasis on environment factor in developed countries is justifiable. According to to the current context social and economic concerns of developing countries should be severly improved to attain the level of improved life patterns of society, In contrast, the developing countries with a series of burning social and economic issues, relatively higher than the environmental issues present in developed countries, require more and more emphasis on social and economic aspects in order to reach a justifiable sustainability assessment. The debatable conclusion drawn is that the developed countries should adhere more towards environmental concerns while the developing countries should keep on emphasizing on social and economic considerations in sustainability assessment.

The final concept of discussion is the need of local benchmarking for sustainable constructions in terms of social and economic aspects. There could be loopholes like weather conditions, cultural context, economic level of the society, benchmarks and indices of sustainability parameters, etc in adapting the existing criterions of sustainability assessment to Sri Lankan context since Sri Lankan conditions are much different from the conditions of the countries which the criterions had been originated. This marks the need of preliminary review and the adjustments of existing criterions, so as to match Sri Lankan context and establishment of appropriate benchmarks in the fields of social and economic, to bridge the gap between international and local frameworks. The development of benchmarks should maintain a close relationship with each indicator in the social and economic categories which would then maximize the highest and best applicability and comprehensiveness of the assessment criterions.

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APPLICATION OF THE SAFE WORKING CYCLE (SWC) IN HONG KONG CONSTRUCTION INDUSTRY: LITERATURE REVIEW AND FUTURE RESEARCH AGENDA

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ABSTRACT

The accident rate of the Hong Kong construction industry is very high when compared with other developed countries. Since 1990, the industry has introduced different safety initiatives to minimize the occurrence of site accidents, and there has exhibited a significant decrease in accident rate over the years. The Safe Working Cycle (SWC) is one of the effective safety measures aiming to ensure a tidy working site and raise the safety awareness of construction workers everyday. It comprises the Daily Cycle, Weekly Cycle and Monthly Cycle, and it focuses on the causes of construction accidents and improves the overall safety performance on construction sites. This paper will provide a concise introduction of a research project in relation to SWC in the Hong Kong construction industry. It aims to scrutinize the overall research paradigm of a holistic study on the historical development, underlying concepts and applications of SWC in Hong Kong. The investigation will be accomplished by a combination of data collection methods comprised of archival desktop study, in-depth interviews, detailed case studies and an empirical questionnaire survey. Relevant attributes of SWC including the perceived benefits, potential difficulties and effective recommendations for future implementation will be explored and discussed herein. The research findings are expected to help the decision-makers to generate clearer insights into the effectiveness of SWC in improving site safety, and to allow industrial practitioners to explore whether and how the site accidents can be mitigated via SWC.

Keywords: *Construction Industry; Hong Kong; Safe Working Cycle; Safety Measure; Site Safety Performance.*

1. INTRODUCTION

The high-rise buildings in Hong Kong such as the International Commerce Centre and Two International Finance Centre are noticeable in height of higher than 400 metres. Similarly, the accident rate of the Hong Kong construction industry is also high when compared with other developed countries (Choi *et al*., 2012). The industry has introduced different safety initiatives to minimize the occurrence of site accidents since 1990, and there was a significant decrease in accident rate over the years. Nevertheless, the accident rate of the construction industry is still comparatively higher than other major industry sectors (Labour Department, 2011) and other overseas regions. This study will focus on the issue of construction safety in Hong Kong because of the above reason.

The major causes of construction accidents can be basically categorized into management problems, poor working conditions and workers' carelessness (Tang *et al.*, 2003). According to these causes, there were different kinds of safety initiatives that were implemented, such as the Safety Management System (SMS), Performance Assessment Scoring System (PASS), Pay for Safety Scheme (PFSS) and Safe Working Cycle (SWC) (Rowlinson, 2007).

The SWC, also named as the Site Safety Cycle (SSC), was modelled from the Japanese construction industry (Highways Department, 2002). As Japan has maintained a good safety record when compared with Hong Kong (Occupational Safety and Health Council, 2001), SWC is believed to be an effective safety measure in improving the prevailing situation in Hong Kong.

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The SWC is a safety measure embodying a well-organized safety management system. It comprises the Daily Cycle, Weekly Cycle and Monthly Cycle (Li and Poon, 2007). The aim of SWC is to ensure a tidy working site and raise the safety awareness of construction workers every day (Occupational Safety and Health Council, 2006). It does focus on the causes of construction accidents and improves the overall safety performance on construction sites.

The SWC has been widely adopted in the Hong Kong construction industry particularly in the public sector. It was applied to all public works projects since 15 August 2002 (Highways Department, 2002), such as the Environment, Transport and Works Bureau (Environment, Transport and Works Bureau, 2002).

Due to these underlying reasons, the SWC is chosen to be the core of this study since it is regarded as one of the effective safety measures. The investigation of the effectiveness of SWC can assess the site safety performance in the past and now. The exploration of the difficulties in implementing it can allow us to improve the implementation of SWC in future.

2. RESEARCH AIM AND OBJECTIVES

The SWC has been implemented in the Hong Kong construction industry for almost 10 years since 15 August 2002 and there exhibited a downward trend in accident rate. However it is a doubt about the relationship between the implementation of SWC and the site safety performance. The research aims are to explore the application and effectiveness of SWC in accident prevention and reduction, and what are the difficulties in implementing SWC in Hong Kong, based on literature review, in-depth interview, case study and questionnaire survey. In order to achieve the aim, the research objectives are set out as follows:

(a) To provide a critical overview of current application of the SWC in Hong Kong.

(b) To investigate the effectiveness of the SWC in improving the site safety performance of construction projects.

(c) To determine the key features, perceived benefits and potential difficulties of implementing the SWC and analyze their relative importance.

(d) To suggest insightful recommendations for the successful implementation of SWC in the Hong Kong construction industry.

The proposed research is timely and indispensable because SWC has been introduced in the public sector since August 2002. It is timely for us to review its effectiveness in upgrading the site safety performance and seek further improvement for future use. The research findings are also expected to allow industrial practitioners to investigate whether and how the site accidents can be mitigated via SWC.

3. BACKGROUND OF RESEARCH

3.1. SAFETY PERFORMANCE OF THE CONSTRUCTION INDUSTRY IN HONG KONG

Safety on construction sites in Hong Kong remained a prime concern despite significant improvements were recorded in 2001-2010 (Labour Department, 2011). The high-risk construction industry still recorded the highest accident rate and number of fatalities amongst various major industry sectors. As compared with 2009, the number of construction accidents recorded in 2010 soared from 2,755 to 2,884 by 4.7%, while the accident rate per 1,000 workers dropped from 54.6 to 52.1 by 4.5% (Labour Department, 2011). The occurrence of site accidents always generates a risk on construction projects which is not only delay the completion date but also cause enormous financial losses and even casualties.

3.2. CONSTRUCTION SAFETY INITIATIVES IN HONG KONG

In order to deal with the causes of construction accidents, there were different kinds of safety initiatives that have been introduced and implemented. Rowlinson (2007) listed out all major safety initiatives such as the Safety Management System (SMS), Pay for Safety Scheme (PFSS), Performance Assessment Scoring System (PASS) and Safe Working Cycle (SWC) introduced by the government from 1994-2005 (Table 1). The safety initiatives which have been undertaken to improve the site safety performance can be categorized into four aspects – *Statutory, Financial, Procedural* and *Punitive-administrative*.

Statutory initiatives are based on the Hong Kong Ordinances, together with the Occupational Safety and Health Ordinance (Construction Industry Institute – Hong Kong, 2009). Examples are the Factories and Industrial Undertakings (Safety Management) Regulations enacted in 1999, and the amendments to the Construction Sites (Safety) Regulations in 2003 (Rowlinson, 2007).

Table 1: Summary of the Major Construction Safety Initiatives in Hong Kong from 1994 to 2005 (Source: Rowlinson, 2007)

Year	Major Construction Safety Initiatives
1994	Safety Management System (SMS)
1994	Pay for Safety Scheme (PFSS)
1994	Performance Assessment Scoring System (PASS)
1994	Safety Plan
1995	Consultation Paper on Self-Regulatory SMS
1996	Green Card Scheme: Mandatory Safety Training Programme
1997	Construction Sites (Safety) Regulations
1997	Factories & Industrial Undertakings Regulations
1997	Occupational Safety and Health Ordinance (Cap 509)
1998	Construction Site Safety Manual and Handbook
1998	Site Supervision Plan System
1998	Occupational Safety and Health Regulations
1999	Factories and Industrial Undertakings (Amendment) Ordinance
2000	PASS (Revised to include PFSS provision)
2000	Contractor Performance Index System
2000	Code of Practice for Site Safety Supervision
2001	Automatic Suspension from Tendering System
2002	Safe Working Cycle (SWC)
2002	Factories and Industrial Undertakings (Safety Management) Regulations
2002	Code of Practice on Safety Management
2003	Construction Sites (Safety) (Amendment) Regulations
2005	Safety Partnering Programme

Financial initiatives – Works Bureau launched PFSS in public works projects aiming at motivating the contractor to improve the site safety performance since 1996 (Rowlinson, 2007). It includes a fixed sum under the 'site safety section' in the Bill of Quantities. Safety-related items will be priced based on total payment to the contractor (Fong, 2000).

Procedural initiatives are process-based which included the PASS and SWC. They are incorporated in the construction contract for requiring the contractor to achieve a certain level of safety performance (Construction Industry Institute – Hong Kong, 2009).

Punitive-administrative initiatives are referring to those punishments to the contractors who encounter serious accidents on their sites. Examples are the Automatic Suspension from Tendering System promulgated in 2001 (Construction Industry Institute – Hong Kong, 2009).

The performance of those construction safety initiatives is reflected in Figure 1. Tang (2007) mentioned three stages of those safety initiatives: Stage 1 is the technical improvement stage, Stage 2 is the system improvement stage, and Stage 3 is the safety culture building stage. The industry is now in the Stage 3 which the core features of the safety initiatives are being focused on the culture building.

The cultivation of safety culture can be through the implementation of Safe Behaviours. The most popular and recent one is the SWC which originated from Japan. As the Japanese Construction Industry has a significant improvement on site safety records after implementing the SWC and the number of accidents declined significantly (Occupational Safety and Health Council, 2006).

4. BACKGROUND OF SAFE WORKING CYCLE

In 2000, the SWC was introduced to the Hong Kong construction industry, which is modelled from a safety initiative from the Japanese Construction Industry - Safe Working Cycle (Environment, Transport and Works Bureau, 2002). SWC was adopted under the PFSS in six designated contracts for trial run. SWC has been formally launched after two years of trial run and applies to all public works projects (PWP) and capital works contracts since 15 August 2002 (Highways Department, 2002; Environment, Transport and Works Bureau, 2002).

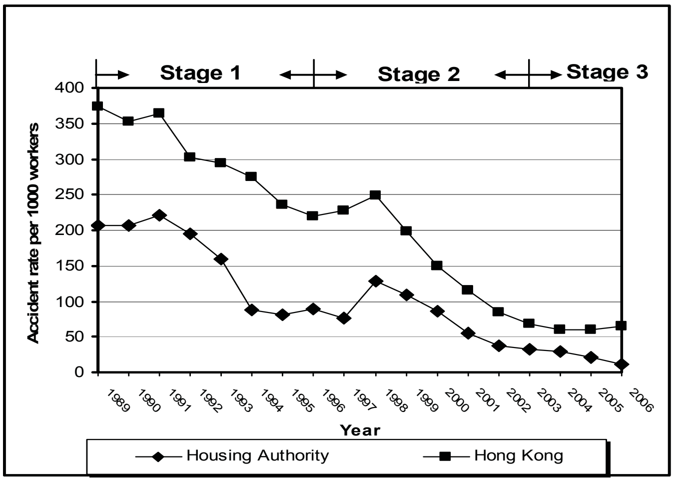

Figure 1: Accident Rate Per 1,000 Workers in Construction Industry (1989-2006) (Source: Tang, 2007)

5. GOALS OF SAFE WORKING CYCLE

The implementation of SWC is aimed to enhance the communication between the safety managers/supervisors and construction workers. It helps raise the workers' safety awareness and ensure a safe site condition (i.e. good housekeeping and tidy site). By achieving those objectives, SWC helps improve the site safety performance and prevent the occurrence of accidents on sites (Environment, Transport and Works Bureau, 2002). The implementation of SWC is aiming at cultivating safety habit for all project team members. It helps develop a safety culture on construction sites and foster safe behaviours of the workers through the repetitive procedures every day (Ozaka, 2000).

6. TYPES OF SAFE WORKING CYCLE

There are three types of cycles and 15 items under SWC, namely Daily Cycle (Table 2), Weekly Cycle (Table 3) and Monthly Cycle (Table 4). The details of each cycle are indicated as follows:

6.1. "DAILY" SAFE WORKING CYCLE

The Daily Cycle comprises 8 items and they are scheduled with relevance to the project schedule and can be presented on a time chart. Every involved person should perform their responsibilities based on the time schedule. Each organization should regulate the working hours for each items by considering the characteristics of the project (Occupational Safety and Health Council, 2006).

Table 2: List of Items in Daily Cycle of Safe Working Cycle

Safe Working Cycle (Daily Cycle)		
	Items	**Participants**
(a)	Morning Safety Meeting	All Workers
(b)	Hazard Identification Activity (HIA)	All Work Teams
(c)	Prior-to-Work Inspection	Engineers, Competent Persons, Plant Operators etc.
(d)	Safety Inspection	Project Managers, Site Agents, etc.
(e)	Guidance and Supervision at Work	Team Representatives, Foremen, etc.
(f)	Process Safety Discussion	Project Managers, Site Agents, Foremen, etc.
(g)	Tidying up after Work	All Workers
(h)	Final Check after Work	Team Representatives, Foremen, etc.

6.2. "WEEKLY" SAFE WORKING CYCLE

The Weekly Cycle is an overview of the safety performance in the past week and identifying the problems, and it facilitates the improvement of safety measures for next week and in the future. It consists of 3 steps – inspection and check, process safety discussion and weekly tidying up (Occupational Safety and Health Council, 2006).

Table 3: List of Items in Weekly Cycle of Safe Working Cycle

Safe Working Cycle (Weekly Cycle)		
	Items	**Participants**
(a)	Weekly Safety Inspections and Weekly Check Up	Inspections: Project Managers, Site Agents, etc. Check-up: Engineers, Competent Persons, Plant Operators etc.
(b)	Weekly Process Safety Discussion	Project Managers/Site Agents, Safety Officers, Subcontractor Representatives, etc.
(c)	Weekly Tidying up	All Workers

6.3. "MONTHLY" SAFE WORKING CYCLE

The Monthly Cycle is aimed at reviewing the site safety performance and the works' progress. The safety training can enhance the worker's safety awareness. The promotional campaign is organized to provide recognition of their efforts and safety performance (Occupational Safety and Health Council, 2006).

Table 4: List of Items in Monthly Cycle of Safe Working Cycle

Safe Working Cycle (Monthly Cycle)		
	Items	Participants
(a)	Monthly Inspection	Engineers, Competent Persons of Principal Contractor and Subcontractor
(b)	Monthly Safety Training	Safety Officers and All Workers
(c)	Monthly Safety Meeting	All Workers
(d)	Safety Committee Meeting	Members of the Safety Committee

An extensive review of various reported literature has provided the background information for the research on the effectiveness of Safe Working Cycle. The information includes the safety performance of the Hong Kong construction industry over the past decade, different safety initiatives being adopted in Hong Kong and the most important one among others, is the introduction of Safe Working Cycle.

7. RESEARCH METHODOLOGY

7.1. OVERALL RESEARCH APPROACH

Four research tools, i.e. literature review, in-depth interview, case study and questionnaire survey will be used in collecting appropriate and sufficient information and data of projects using SWC based in Hong Kong. Figure 2 demonstrates the overall research framework with reference to the concept of Walker (1997)'s model.

7.2. LITERATURE REVIEW

Desktop search is a direct approach to obtain the useful information. It is a comprehensive review of the related literature sought from journal articles, reference textbooks, conference papers, previous dissertations and on-line materials on SWC, as previously adopted by Chan *et al.* (2011). The information will reveal the present state of site safety performance and safety initiatives in Hong Kong. These will lead to the construction of a background picture for further understanding of SWC. The understanding of background information will facilitate the preparation of the interviews and survey questionnaire, so as to acquire the relevant information.

7.3. IN-DEPTH INTERVIEW

To gain an in-depth understanding of the current practices of SWC, qualitative approaches including pilot interviews and structured interviews will be undertaken. Face-to-face interviews will be employed to solicit information and opinions from the construction practitioners, including both public and private sectors, as used by Chan *et al.* (2007). The selected target organizations will include government works departments and contractors. The target interviewees cover project managers, safety managers/officers and engineers with direct hands-on experience in undertaking the SWC. Experienced and knowledgeable persons in construction projects can provide specific, detailed, valuable information and comments on an in-depth study on the effectiveness of SWC and the difficulties in implementing it.

More than 10 target interviewees will be invited to an interview. The number of interview questions will be limited to 10 only due to the availability of time and avoidance of a tedious interview. A pilot interview will also be carried out as a mock-up and allow for rectifying the ambiguity and deficiency of the interview questions. The interview questions will basically be divided into two parts. Part A will aim at acquiring the basic information about the interviewee and his/her company. Part B will focus on the chosen research area which is the effectiveness of SWC, benefits and difficulties of implementing it, and any recommendations for improving its current implementation. The structure of the interview is indicated in Table 5. After conducting the interviews, the interviewee's responses will be summarized in a table, and the comparison and contrast will be carried out for further data analysis and discussion.

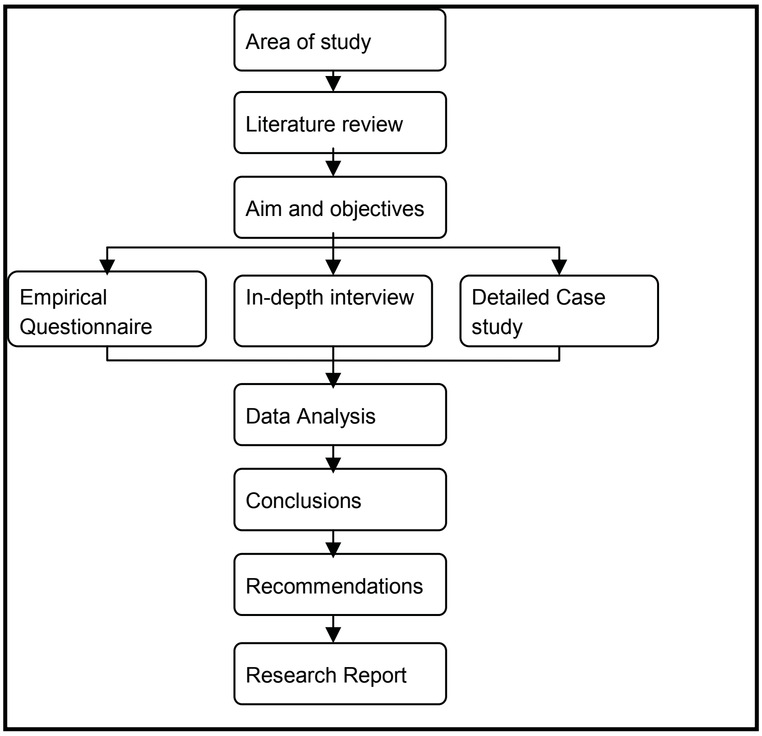

Figure 2: Research Framework for the Proposed Study

7.4. IN-DEPTH INTERVIEW

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Table 5: Structure of the Interview

Part	Target Information
A	Basic Information about the Interviewee and his/her Company
B	Comments and Responses on the (1) Effectiveness of Safe Working Cycle (SWC) (2) Benefits and Difficulties of Implementing SWC (3) Recommendations for Improving SWC

7.5. *CASE STUDY*

Case study methodology will also be adopted in this study as by Chan *et al.* (2010) before. Data on the relevant real-life case study projects of using SWC will be collected through face-to-face interviews and retrieval from collaborating firms. In-depth investigation on some case study projects is not only used to enhance the real understanding of the practice and implementation of SWC, but also it is vital to validate the research findings. All the cases will be analyzed on both an individual basis and collectively in order to draw valid, representative conclusions.

7.6. *EMPIRICAL QUESTIONNAIRE SURVEY*

The use of empirical questionnaire survey will provide a structured format to obtain the necessary information and opinions on the SWC adopted on construction sites (Chan *et al.*, 2011). The sample size of questionnaire will be expected to be as large as possible (more than 30), and a larger sample size will allow the result to be more representative and reliable.

In order to increase the response rate, the questionnaire will be designed to 2-3 pages only. The questions to be asked only require short answers in form of ticking boxes and writing a few words. The design of this format aims to minimize the time spent by and inconvenience caused to the interviewee on completing the questionnaire. A pilot questionnaire will also be launched as a mock-up and allows for rectifying the ambiguity and deficiency of the questionnaire. The questionnaire survey will be distributed to the target respondents who are mainly Project Managers, Safety Managers/Officers and Engineers from both public and private sectors who have obtained direct hands-on experience in projects with SWC.

The areas of questions will be categorized into two parts. Part A is the basic information about the respondents and his/her company. Part B focuses on the current practice of SWC. The main objectives of the questionnaire are to evaluate the effectiveness of the implementation of SWC in improving site safety performance and evaluate the potential benefits and difficulties of implementing the SWC.

The evaluation will be based on the level of effectiveness of the essential items in the SWC and the level of agreement on the potential benefits and difficulties of implementing the SWC. The structure of the questionnaire shows as follows:

Table 6: Structure of the Survey questionnaire

Part	Target Information
A	Basic Information about the Respondent and his/her Company Indication on the Level of Effectiveness of the Essential Items in Safe Working Cycle (SWC) in Achieving Better Site Safety Performance: (1) Daily Cycle (8 Items) (2) Weekly Cycle (3 Items) (3) Monthly Cycle (4 Items)
B	Indication on the Level of Agreement on the Potential Benefits and Difficulties of Implementing the SWC: (1) Benefits (2) Difficulties

A five-level of effectiveness or agreement will be provided for each question as the basis for calculating the mean score of each item in SWC and benefits and difficulties of implementing SWC. The respondent's responses will be used for further data analysis through the ranking of mean scores. The mean score will be calculated by the following formula (Chan *et al.*, 2011):

$$\text{Mean score} = \frac{\sum(\text{Frequency of responses received x Score given by respondents})}{\text{Total number of responses received}} \qquad \text{(Equation: 01)}$$

where 1 = Strongly disagree; 3 = Neither agree nor disagree; and 5 = Strongly agree (1 ≤ Mean Score ≤ 5)

8. 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 questionnaire survey and case studies 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 the SWC on construction sites will be organized to generate relevant information and to supplement and/or confirm the outcomes of the analyses, and a set of possible recommendations for improving the implementation of SWC. A meeting will be scheduled via discussions and moderations to validate the research findings and explanations with practitioners involved in the study.

9. CONCLUSIONS

This research study will launch an in-depth investigation of implementing the Safe Working Cycle (SWC) in the Hong Kong construction industry. It will provide a critical review of the current application, features, benefits and difficulties of applying Safe Working Cycle (SWC), together with improvement measures for successful implementation. By consolidating the different opinions on the above attributes of PFSS between clients, consultants and contractors, project team members can maximize the perceived benefits obtained from and minimize the potential difficulties of adopting SWC. Moreover, the results will establish a positive environment on future development of SWC and encourage the private property developers to implement SWC in the near future.

10. ACKNOWLEDGMENTS

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APPROACH TO SUSTAINABLE DEVELOPMENT THROUGH ARCHITECTURAL EDUCATION: INSIGHT TO THE PERCEPTIONS OF SRI LANKAN STUDENTS

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ABSTRACT

Sustainable development is considered as a multi-dimensional problem for integration of economic, environmental, institutional, political, social and personal human problems. Therefore, interdisciplinary interaction will be essential to reach the ultimate goals of sustainability. Architecture, as a key profession in the construction sector, plays a significant role in promoting the interdisciplinary interaction and a holistic approach to sustainable development. This approach requires a high amount of knowledge, skills and attitude which could be obtained through architectural education.

The need of approaching sustainable development through education was accepted by the United Nations and has declared 2005 to 2014 as the decade of Education for Sustainable Development (ESD). Therefore, this paper intends to explore the relationship between the architectural education and sustainable design practice in the Sri Lankan context.

Architectural educational content on sustainable development has two folds, such as, the technical component and non-technical component. The technical components mainly focus on providing knowledge and skills, which are more applicable towards the latter parts of the design process (design detailing). Non-technical components not only provide knowledge and skills but also attitude and could be applied from the early stages of the design process (Concept development, brief interpretation, etc).

The methodology adopted is a survey (structured) research approach where data generated through a social survey and a literature survey would be analysed to reflect some thoughts. Social survey would be conducted through a structured questionnaire given to undergraduates and young practitioners of architecture from the two main schools of Architecture in Sri Lanka (City School of Architecture, Colombo and Department of Architecture, University of Moratuwa). Student perception on Sustainability would be explored through the parameters of personal interpretations, application frequency and satisfaction to non-satisfaction ratio. Reflections would include that the technical knowledge and skills need to be in equilibrium with the non-technical knowledge and attitudes given in architectural education to obtain a more holistic sustainable design approach.

Keywords: *Architectural Design; Architectural Education; Education for Sustainable Development (ESD); Sri Lankan Architecture Student Perception; Sustainable Development.*

1. INTRODUCTION

The Second World Summit on Sustainable Development (WSSD) convened in Johannesburg in 2002 recognised that education had the potential to play a major role in the future realisation of a 'vision of sustainability that links economic well-being with respect for cultural diversity, the Earth and its resources' (UNESCO, 2007, p. 6). Subsequently the United Nations General Assembly adopted Resolution 57/254 and declared the period 2005–2014 as the Decade for Education for Sustainable Development (DESD). The overall goal of the DESD, led by UNESCO, is to integrate values, activities and principles that are inherently linked to sustainable development into all forms of

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education and learning and help user in a change in attitudes, behaviours and values to ensure a more sustainable future in social, environmental and economic terms (UNESCO, 2007, p. 5).

In the light of the DESD, Architectural Education is also considered to be very important because Architecture, which is a key professional in the construction sector, has a direct impact on sustainability in all three spheres of social, environmental and economic contexts. Therefore, sustainable design is considered as a key skill in Architectural Education throughout the world and is taught as compulsory module at different levels of graduate studies. Though students are exposed to sustainable design theories and technologies through these modules, their interpretations, understandings and perceptions on sustainability differ in the practical applications. These perceptions on sustainability can initiate new trend (positive or negative) in sustainable design as these graduate students are the future practitioners of Architecture. Therefore it is very important to explore how students perceive the current architectural education on sustainable design that would influence the future built environment.

Therefore this paper intends to explore how Sri Lankan students of Architecture perceive sustainability during their graduate studies, and what their perceptions are towards the same. This would enable a reflective practice to develop "lessons learned" scenarios, where the results could be shared and any lessons learnt could be put into future practice. In order to move forward in a pertinent manner, it is of prime importance to reveal and confront the underlying conceptions shaping the construct "architectural and environmental education," whether the perspective of sustainable development is fully adopted or is considered from a critical point of view.

2. IMPORTANCE OF THE EDUCATION FOR SUSTAINABLE DEVELOPMENT (ESD)

The notion of sustainable development entered the political centre stage of policy discourse over 20 years ago when the Brundtland Commission used it to connote a development strategy that, in a much quoted statement, 'meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED,1987, p. 43).

Education is an essential tool for achieving sustainability. People around the world recognize that current economic development trends are not sustainable and that public awareness, education, and training are are significant in moving society toward sustainability.

Education for Sustainable Development (ESD) is essentially a call for change in the way we educate our children and ourselves with the express purposes of ensuring a sustainable future. While countries and stakeholders are already interpreting this call in diverse ways UNESCO presents ESD as a development project with four objectives and four thrusts. The objectives are to;

- Facilitate networking, linkages, exchange and interaction among stakeholders in ESD.
- Foster an increased quality of teaching and learning in education for sustainable development.
- Help countries make progress towards and attain the Millennium Development Goals through ESD efforts.
- Provide countries with new opportunities to incorporate ESD into education reform efforts (UNESCO, 2007, p.6).

The four thrusts of ESD are;

- Improving access to quality basic education,
- Reorienting existing education programmes,
- Developing public understanding and awareness and
- Providing training.

With its aim being to change the ways in which children and adults learn to think, value and act, ESD bears many similarities with earlier and parallel curriculum movements such as **environmental education**, peace education, population education, human rights education, citizenship education and development education. While the curriculum and pedagogic approaches and boundaries between these ‘subjects’ or ‘cross-curricula themes’ are sometimes contested by the educators who promote them, they share a commitment to changes in educational content and delivery (Stables and Scott, 2002; McKeown and Hopkins, 2003; Jenkins and Jenkins, 2005). They vary most in terms of their intended reach (from school children to university students, corporate business and policymakers) and content and design (with some emphasizing the delivery of specific messages; others the development of skills of reasoning about and engagement with the wider world) (Scott and Gough (eds), 2004).

Implications of ESD are varied among different disciplines. Therefore it is important to identify particular issues in each discipline to educate in a sustainable manner.

According to Wijesundara and Gunarathna (2012), development sectors in current global context are so vivid that the need for sustainability education will also reflect this diversity. Table 1 below would reflect the different needs of ESD at different levels.

Table 1: Different Needs of ESD at Different Levels of Context/Society (Adopted from Wijesundara and Gunarathne, 2012)

	Level in Context	Needs in ESD
1	Decision makers	make correct decisions that will ensure Sustainable development
2	Educators	integrate of ESD in every possible aspect in teaching
3	Professionals	Provide services within a framework that would not conflict with principles of sustainable development and to make use of appropriate knowledge and skills to make decisions and to take action.
4	Higher education students	Build knowledge , skills and attitudes to take actions towards Sustainable development
5	Primary and secondary education students	Build an attitude towards the sustainable development practices and to seek further knowledge when necessary
6	General public	Build an attitude for best sustainable development practices and to understand the implication if they are violated

Therefore it is important to understand the overall need as well as the specific needs of ESD in each level of society in initiating an ESD programme.

Further, education for sustainable development must promote “creative and effective use of human potential and all forms of capital to ensure rapid and more equitable economic growth, with minimal impact on the environment” (UNESCO, 1992, p.3).

The analytical framework provided by Yves Bertrand and Paul Valois (1992) is useful to critically examine this discourse surrounding education for sustainable development: “competitive needs,” “education for productivity,” “human capital,” etc. It can be observed that the socio-cultural industrial paradigm and its corresponding educational paradigm (rational paradigm) are predominant. Here, education is first and foremost perceived as a “central economic investment for the development of creativity, productivity, and competitiveness,” and as a transfer process where scientific and technical knowledge is favoured (UNESCO, 1992, p.14).

3. ARCHITECTURAL EDUCATION FOR SUSTAINABLE DEVELOPMENT

It is observed that ESD has grown very popular since the UNESCO declaration of the decade for ESD. According to Læssøe, Schnack, Breiting, & Rolls (2009), different countries have incorporated the ESD into unique areas that are appropriate to that country. ESD is most commonly integrated into environmental studies and climatic change and it is widely known as ’Environmental Education’ (EE).

This Environmental Education for sustainable development framework refers to the paradigmatic conception of environment as a resource and to the conception of education as a technological information transfer process. Green buildings, energy efficiency, renewable energy, carbon footprints, environment impact assessments are the commonly taught areas in this field. Therefore, this is mainly education for the environment, aiming to support a certain economic conception of the quality of life. The development notion (adopted here as the basis for education for sustainable development) refers to the "techno-economic conception of development." This very notion, according to Edgar Morin and Brigitte Kern (1993, p. 89), remains tragically under-developed as it "ignores issues of human identity, community, solidarity and culture…"

According to Wijesundara & Gunarathna (2012), identifying the correct Learning outcomes (LOs) is a key to success in any education program and Architectural Education for sustainable Development would find no exemption. Lozano-Garcia, & Rowe (2008), had proposed the following LOs that are also relevant to Architectural education for sustainable development. They are as follows:

Each student will be able to,

1. Define sustainability.
2. Explain how sustainability relates to their lives and their values, and how their actions impact issues of sustainability.
3. Utilize their knowledge of sustainability to change their daily habits and consumer mentality.
4. Explain how systems are interrelated.
5. Learn change agent skills.
6. Learn how to apply concepts of sustainability to their campus and community by engaging in the challenges and solutions of sustainability on their campus.
7. Learn how to apply concepts of sustainability globally by engaging in the challenges and the solutions of sustainability in a world context.

According to Bloom (1956), Educational activities in general have three domains such as;

- Cognitive: mental skills (*Knowledge*)
- Affective: growth in feelings or emotional areas (*Attitude or self*)
- Psychomotor: manual or physical skills (*Skills*)

It is observed that the above seven LOs had been developed in response to the Blooms domains in education. This is summarized in the Table 2 as below:

Table 2: Three Domains in Education and Learning Outcomes of Architectural Education for Sustainable Design

Domain	**Learning Objectives**	**Nature of delivery**
1. Knowledge	1. Define sustainability. 2. Explain how sustainability relates to their lives and their values, and how their actions impact issues of sustainability	Technical and non-technical
2. Attitude	3. Utilize their knowledge of sustainability to change their daily habits and consumer mentality. 4. Explain how systems are interrelated.	Non-Technical
3. Skills	5. Learn change agent skills. 6. Learn how to apply concepts of sustainability to their campus and community by engaging in the challenges and solutions of sustainability on their campus. 7. Learn how to apply concepts of sustainability globally by engaging in the challenges and the solutions of sustainability in a world context.	Technical

The above literature survey and the discussion, reveals that Architectural educational content on sustainable development has two sections, such as, the technical component and non-technical component. Architectural design is the main application of architectural education and its implementation may happen in phases. The combination of these phases could be called as the design process. These phases of the design process are;

a. Concept formulation
b. Brief interpretation
c. Form making
d. Shaping of the building

The technical components mainly focus on providing knowledge and skills, which are more applicable towards the latter parts of the design process (design detailing). Non-technical components not only provide knowledge and skills but also attitude and could be applied from the early stages of the design process (Concept development, brief interpretation, etc).

4. SURVEY: EXPLORE ARCHITECTURE STUDENTS' PERCEPTION ON SUSTAINABILITY

The two main schools of Architecture in Sri Lanka are the City School of Architecture (CSA), Colombo and Department of Architecture, University of Moratuwa. Both Schools have similar syllabuses with similar learning outcomes. Students are offered mandatory modules such as Environmental studies, Climate and comfort, Solar geometry and Green Architecture at Level 1,2 and 4 of the five year degree programme. Twenty number of CSA level 4 students and another ten number of students from level 5, department of architecture were used for this study. These students were given the similarly structured questionnaire, that explored the following parameters on their perception towards sustainable design;

a. Personal interpretations on sustainability
b. Application frequency of sustainable principles in design projects
c. Reason for the application of sustainable design principles(SDP) in design
d. Phase of design process where sustainable principles are applied
e. Satisfaction level of the delivery of the subject sustainability in graduate studies
f. Student recommendations

Thirty opinions for each of the above parameters were collected to explore student perception on sustainability.

5. ANALYSIS OF DATA

The thirty questionnaires mentioned in the section 4 above were analysed based on the said parameters to draw insights to student perception on sustainability. The data and information on the questionnaires were transferred in to concept maps, graphs and charts as shown below.

a) Personal interpretations on sustainability

Students were asked to define sustainability in their own terms. Their definitions had a variety of highlights where certain aspects of sustainability were given more emphasis. The highlighted aspects of sustainability were extracted from their personal definitions and put in to a concept map as shown in Figure 1 below.

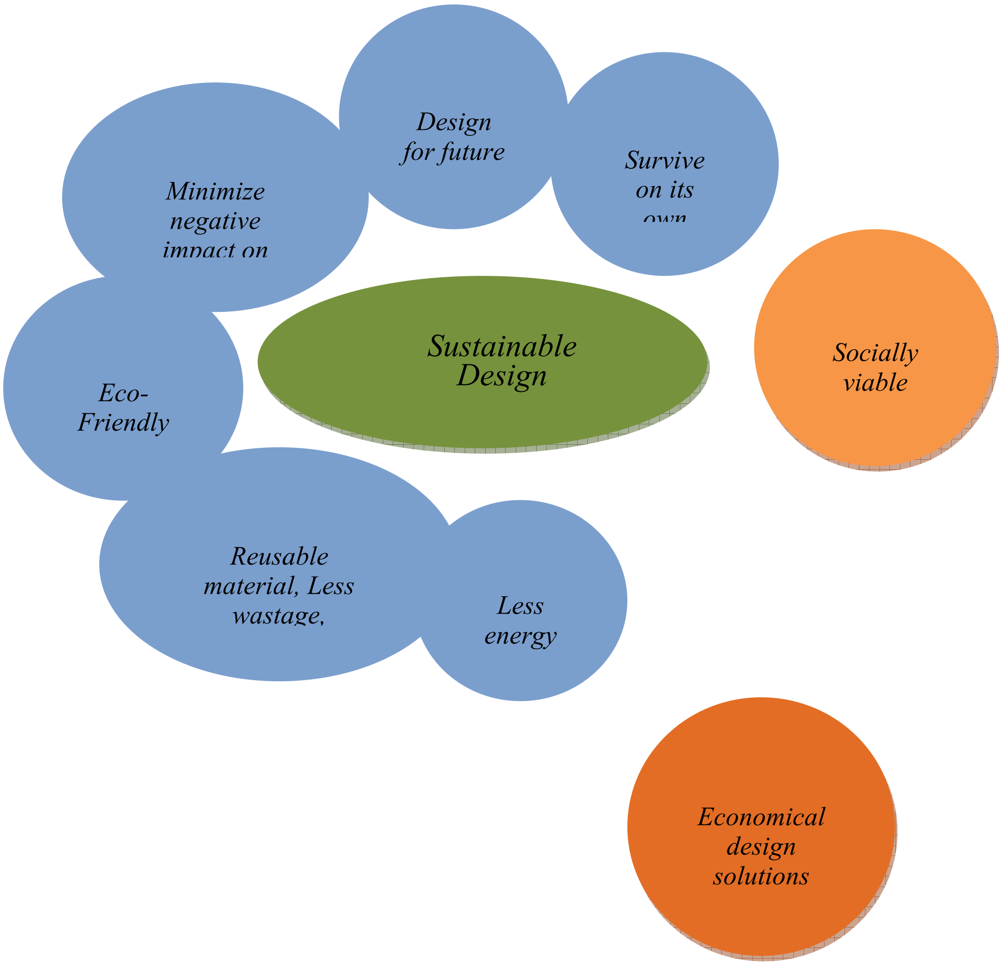

Figure 1: Concept Map: Student's (Architecture) Perceptions on Sustainable Design

Figure 1 show what architecture students consider important when it comes to sustainable design. Further, it also reflects a variety of ideas and that student's emphasis on environment related aspects are higher than socio-economic aspects. This could be further shown through a pie chart as per Figure 2 below. 80% of students perceived sustainability purely through environmental aspects and only 20% remembered the importance of social and economic aspects of sustainability. (Student's definitions were broadly categorized as environmental approach, economic approach & social approach and then counted, in order to get a numerical value)

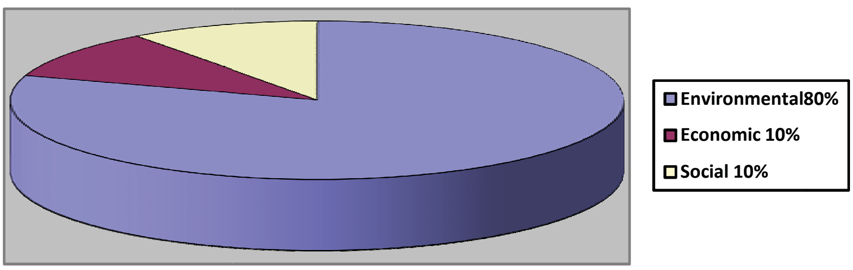

Figure 2: Pie-Chart: (Architecture) Student Emphasis on the Three Main Domains of Sustainable Design

Reflecting on the Figure 1 and 2 above, it could be said that students of Architectural studies perceive sustainability more through the Environmental domain and tend to neglect socio-economic domains which are vital in establishing sustainable developments.

This could be as a result of the imbalance nature of education given through more technically oriented such as environmental studies, climate and comfort, solar geometry where environmental issues are more addressed than socio-economic aspects. Section 3 above discuss on the learning outcomes that need to be obtained in all three domains of education such as Knowledge, Skills and Attitudes. If those learning out comes were achieved through education, students would be able to integrate environmental, economic and social aspects of sustainability.

b) Application frequency of sustainable design principles (SDP) in design projects

In the questionnaire, students were asked about the number of projects (out of all the design project done up to their level of study-approximately 10 projects) they remember as where they applied sustainable theories. Student comments are put on to a table as below (table 1);

Table 3: Architecture Student's Use of Sustainable Principles on Design Projects

No of projects	0/10	1/10	2/10	3/10	4/10	5/10	6/10	7/10	8/10	9/10	10/10
No of students	2	0	12	10	2	0	0	0	2	0	2
% of students	6.6%	0%	40%	33.3%	6.6%	0%	0%	0%	6.6%	0%	6.6%

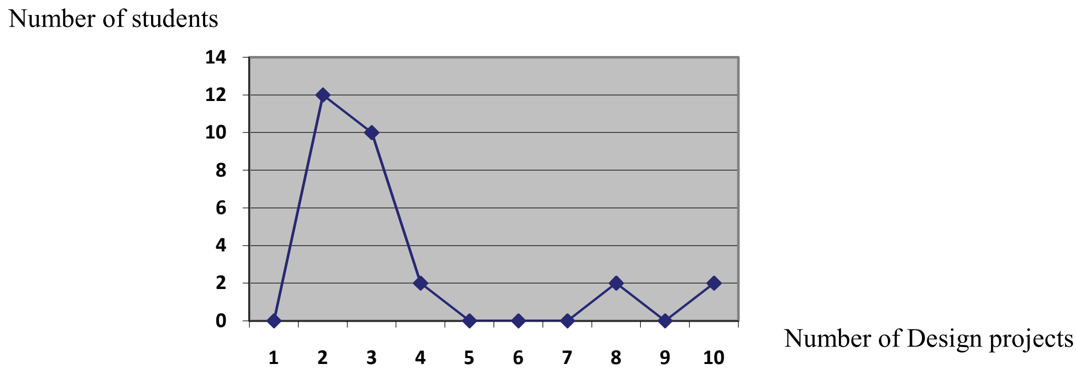

Figure 3: Graph on Architecture Student's Use of Sustainable Principles on Design Projects

Figure 3 and Table 3 above indicate that majority of students (30-40%) have used sustainable design principles in only 2-3 design projects out of about 10 projects up to their level of study. Further, it is also important to note that 6.6% of students have never applied sustainable design principles (SDP) and another 6.6% had used these principles in all the given projects. Therefore, it is important to reflect on the fact that in spite of all the attention given to Sustainability by the whole world its application on the built environment could be less popular.

c) Reason for the application of SDP in design projects

Students were asked whether they applied the sustainable design principles in their projects as they really understood the value of it or as it is an examination requirement. Their comments are put in to the table 2 as below;

Reason for the use of SDPs	Number of students (30)
A. As the true value of Sustainability is understood	7 (23%)
B. As it is an examination requirement	8 (27%)
C. Both reasons	15 (50%)

Table 4: Reason for the Application of SDPs in Design Projects

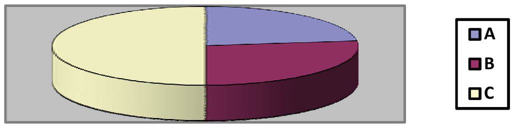

Figure 4: Pie Chart: Analysis of Table 2

Table 4 and Figure 4 above show that the majority students do understand the true value of applying SDPs in design projects; yet there is also a considerable amount of students who do not realise its value and apply them only if it is an examination requirement. These students are the future practitioners of the society and they may contribute less to sustainable developments in the near future. Therefore, it is salient to reduce the percentage of students who do not understand the value of SDPs by improving the education system.

d) Phase of the design process where sustainable design principles are applied

Design is the key module in Architectural studies. A design development can happen in phases and these phases in chronicle sequence are known as the design process. As mentioned in the section 3 above, these phases of the design process could be broadly identified as follow:

a. Concept formulation
b. Brief interpretation
c. Form making
d. Shaping of the building

The given questionnaire inquired students to identify the design phase in which they mainly initiate to apply the SDPs during their design projects. The data generated through the survey was put in to a graph as shown in the Figure 5 below;

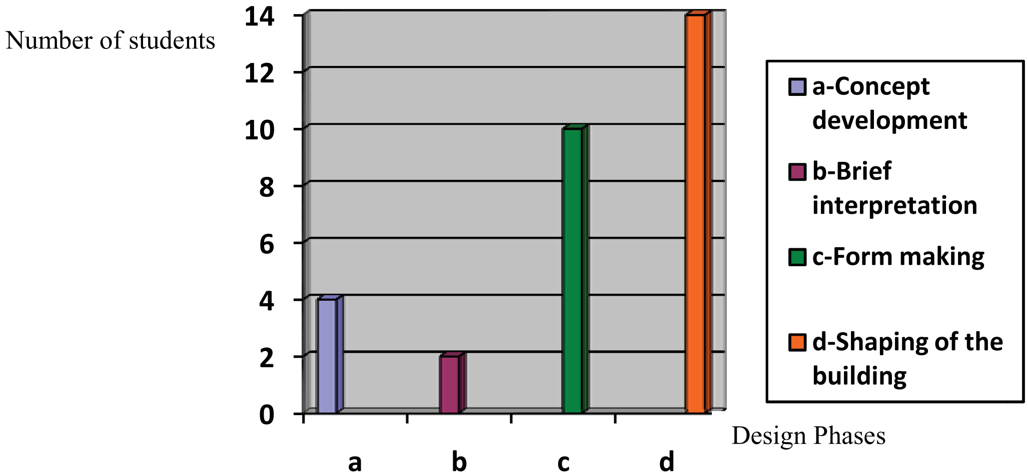

Figure 5: Phase of the Design Process where SDPs are Applied by Students

Figure 5 above reveals that majority of students apply SDPs towards the latter part of the design process. This means that most of the student designs are just wrapped up with SDPs without producing truly a homogeneously sustainable design. During the last two phases (c and d) of form making and shaping students tend to use more technical knowledge by incorporating green technologies such as the use of solar panels, sun shading devices, recycled materials, etc and call it as a sustainable design.

According to the theories discussed above, this alone is not truly sustainable and can be considered as an incomplete approach to sustainable development. First two phases of concept development and brief interpretation involves non-technical knowledge, skills and attitudes. Therefore it is acceptable to consider SDPs applied from early design phases are more complete in approaching sustainable development.

e) Satisfactory level of the delivery of the subject sustainability in graduate studies

Students were asked whether they were satisfied or not satisfied with the delivery of the modules related to SDPs during their education period and the data are transformed in to the graph shown in the Figure 6 below;

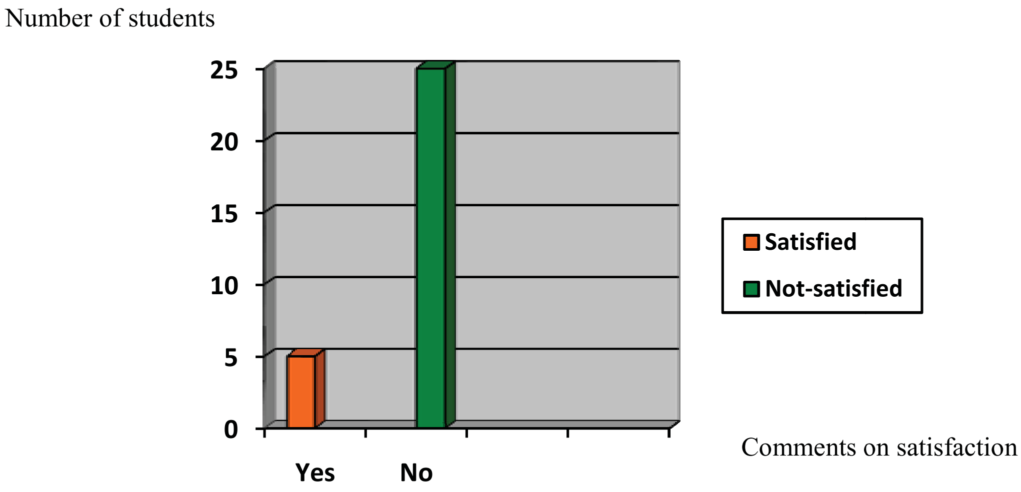

Figure 6: Graph Showing the Satisfactory Levels of Students on the Delivery of Sustainable Design Modules

Figure 6 reflects that the students were more unsatisfied about how they were exposed to modules relevant to sustainable design during their graduate studies. In one of the questionnaires, a student had said that *"Everybody talks about sustainability; but only in very far that it is really explained how to use sustainability in design. What we all do is using materials that are labelled as sustainable and incorporate to the design"*. This clearly shows that in the education system there is a gap between the theories taught and their application in design projects.

f) Student recommendations

Student recommendations on improving Architectural education on sustainable developments were extracted and summarized in to a concept map as shown in the figure 7 above. These recommendations are salient in improving education in response to sustainability.

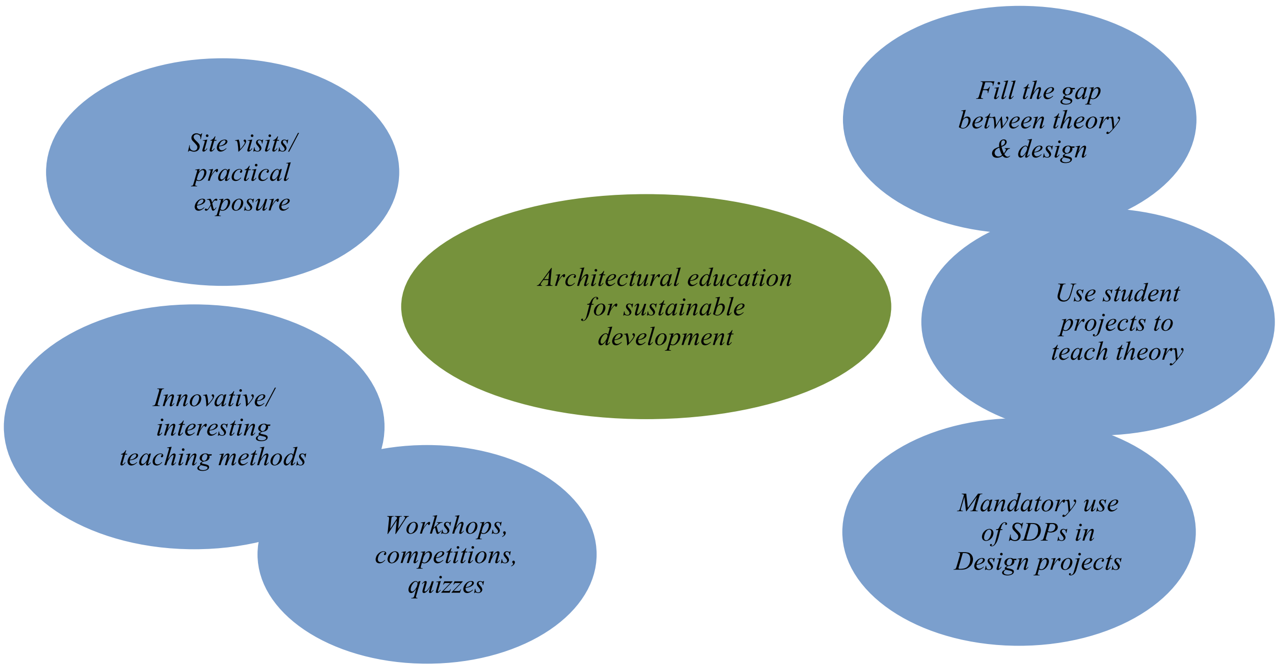

Figure 7: Concept Map: Student Recommendations to Improve Architectural Education for Sustainable Development

6. CONCLUSIONS (KEY FINDINGS & RECOMMENDATIONS)

Architecture is a salient profession in sustainable developments. Therefore, Education for Sustainable Development (ESD) is crucial in Architectural Education. Student perception on sustainable design could be considered as an indicator of the success of Architectural Education on Sustainable development. Therefore, this research paper looked in to perceptions on sustainability of Sri Lankan students from architectural studies through a questionnaire survey and following conclusions were derived;

- Students of Architectural studies perceive sustainability more through the Environmental domain and tend to neglect socio-economic domains which are vital in establishing sustainable developments.
- Use of Sustainable design principles(SDPs) in design projects are considerably less during graduation studies
- Considerable amount of students do not realise the value of sustainable design and apply SDPs only if it is an examination requirement.
- Majority of students apply SDPs towards the latter part of the design process (form making and shaping) and not at early stages such as the concept development and brief interpretation.
- Majority of students are not satisfied on how subjects related to sustainable design were delivered and students see a gap between theory and design.

Based on the above findings and student recommendations following suggestions could be made to improve Architectural education for sustainable development;

- Eliminate the gap between SDP theories and design projects by making SDPs as an essential assessment criteria in design projects, continuous monitoring of the application of SDPs in design projects, etc.

- Promote innovative and interesting teaching strategies such as workshops, competitions, quizzes, etc in delivering modules related to sustainable design
- Site visits and practical sessions to enhance a better understanding on the subject

The above study emphasised the need of improving Architectural education to achieve a holistic sustainable development that caters to all three spheres of environmental, economic and social aspects by balancing the technical and non-technical approaches in education.

7. FURTHER STUDIES

The above study was based on a survey done by using a general questionnaire. Further studies could be done by analysing a design project and explore the relationship between the design phases and sustainable design principles for the development of Architectural education for sustainable development.

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ASSESSING THE BIM MATURITY IN A BIM INFANT INDUSTRY

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ABSTRACT

Building Information Modelling (BIM) is rapidly gaining acceptance of building industries internationally, and is likely to become the primary industry standard for AEC information exchange in near future. The built-in intelligence of BIM offers the highest potentials for adopting lean approaches for project delivery, and minimizing of risks and uncertainties; enabling highly sustainable procurement systems for the building industry. While it is accepted that BIM is in its infant stage in Sri Lanka and BIM technologies are rarely present, adoption of BIM has been identified to be timely. Use of inappropriate BIM adoption strategies would waste valuable resources and time. This will also hinder the industry acceptance of BIM. Development of reliable strategies requires information on current BIM maturity in order to identify the gaps. Wider gaps in a BIM infant industry give rise to the number of potential alternative BIM adoption strategies. Thus, a coherent assessment of current context is crucial to chose most suitable strategies. Bew-Richards BIM Maturity Model and Succar's BIM Maturity Stages were the widely referred models used to ascertain the BIM maturity of an industry or an organization. However, these were found to be less useful to assess a BIM infant industry. The study proposes framework comprising four components, viz. collaborative processes, enhanced skill, integrated information and automated systems, and knowledge management.

Keywords: *Building Information Modelling (BIM); BIM Adoption; BIM Maturity.*

1. INTRODUCTION

Building Information Modelling, or BIM as it is commonly referred to, is digital representation of physical and functional characteristics of a building creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition (CPIC, 2011). The technological developments in BIM bring the construction to a new era. Contrast to the conventional ICT developments in the field of construction, BIM is based on a strong information schema which makes the building design fully machine readable. This enables automation of various design, construction management, quantity surveying and procurement processes; and minimizing of design and construction errors. Thus it offers the highest potentials for adopting lean approaches for project delivery, and minimizing of risks and uncertainties; enabling highly sustainable procurement systems for the building industry.

BIM has gained gradual popularity in United States and few European countries, especially in Finland (Khosrowshahi & Arayici, 2012), over the decade, while United Kingdom looked for a kick-start in BIM with the UK Cabinet Office announcing the Government's new Construction Strategy in mid 2011 (Poletayeva, 2011). The report announced the Government's intention to require collaborative BIM (with all project and asset information, documentation and data being electronic) on its projects by 2016. Sri Lanka however, possessing a BIM infant industry (see Jayasena & Weddikkara, 2012), should be able to strategically adopt BIM if and when the requirement arises. In such and endeavour, the use of inappropriate BIM adoption strategies would waste valuable resources and time. This will also hinder the industry's acceptance of BIM. Development of reliable strategies requires information on current BIM maturity in order to identify the gaps. Wider gaps in a BIM infant industry give rise to the number of potential alternative BIM adoption strategies. Thus, a coherent assessment of current context is crucial to chose most suitable strategies. This paper presents a literature synthesis aimed to identify a suitable framework for assessing the BIM maturity in a BIM infant industry.

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2. BIM MATURITY

BIM maturity and developments have been widely discussed by various authors (e.g., Khosrowshahi & Arayici, 2012; Laakso & Kiviniemi, 2012; Owen *et al.,* 2010; Succar, 2009; Suermann & Issa, 2007; van Berlo, Beetz, Bos, Hendriks, & van Tongeren, 2012). Since BIM is a technique, its maturity in an industry shall be observed from its applications. For an assessment of the level of maturity, it is also essential to define the highest level of maturity.

Two maturity models, viz. Bew-Richards BIM maturity model and Stages of BIM maturity by Bilal Succar, have been used in discussing and ascertaining BIM maturity. It was observed that both models were developed by reviewing the natural maturity occurred and envisaged future of practical implementations of BIM and related techniques.

2.1. BEW-RICHARDS BIM MATURITY MODEL

The Bew-Richards BIM Maturity Model shown in Figure 1 is the most widely used maturity model to discuss the BIM maturity in an industry or an organization.

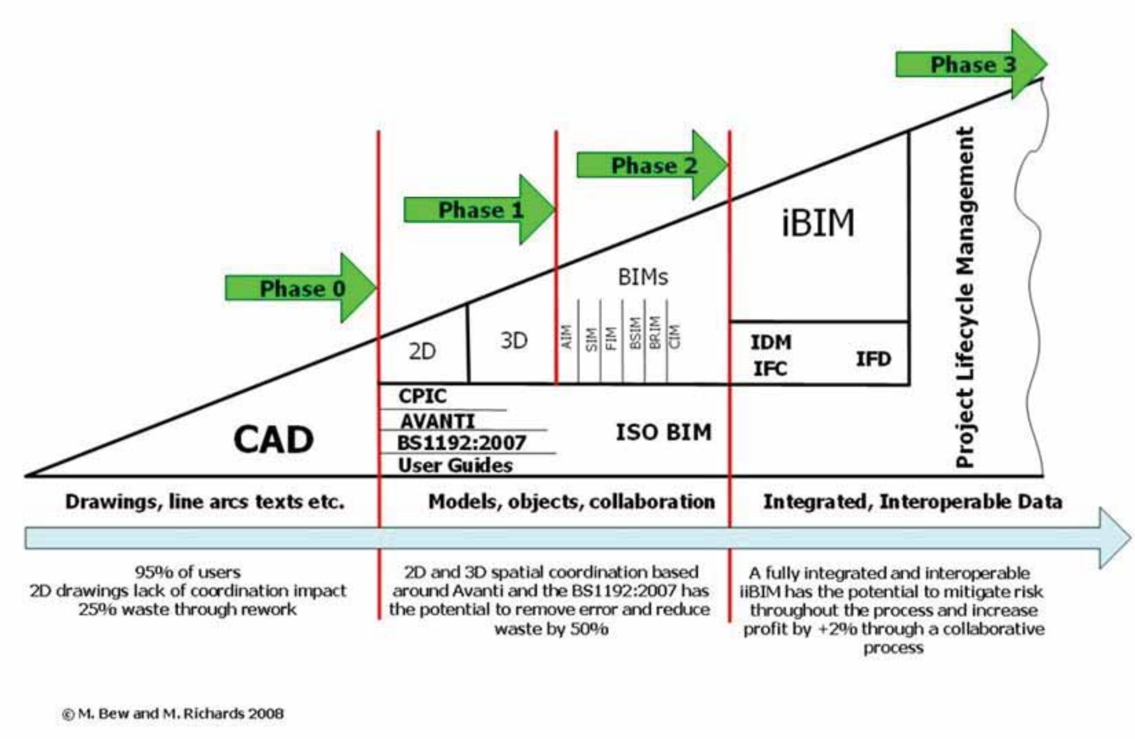

Figure 1: Bew-Richards BIM Maturity Model (Bew & Richards, 2008)

Bew-Richard model identifies basic CAD (Computer Aided Draughting) as "*Phase 0*", i.e. "*no BIM maturity*". At this phase, CAD is used as a replacement for conventional drawing board, representing information using lines and curves on a 2D plane. In these drawings no intelligence such as layering and blocks are expected. The model considers use of intelligence on basic CAD usage as the entry into early BIM maturity phase. A BIM infant industry will find itself in *Phase 0*, or at most at the entry of *Phase 1*. An industry which is already in *Phase 1* or higher shall not be considered as '*infant*'.

Phase 1 starts with introduction and application of best practices such as those introduced by CPIC and supported standards. BS1192:2007 "establishes the methodology for managing the production, distribution and quality of construction information, including that generated by CAD systems, using a disciplined process for collaboration and a specified naming policy. The standard is applicable to all parties involved in the preparation and use of such information throughout the design, construction, operation and deconstruction of projects and throughout the supply chain" (ICE, 2009, p. 1). This is well supported by the *Code of Procedure for the Construction Industry* established by CPIC. Through this, CPIC aims to provide practical guidance on the preparation of good production drawings, specifications and schedules of work and the methods used to co-ordinate the information contained within. AVANTI is also a CPIC initiative with the objective of helping to deliver improved project and business performance through the use of ICT to support collaborative working (CPIC, 2007). A BIM infant industry may directly apply those or use them as concepts and guides to make their own standards.

2.2. *SUCCAR'S STAGES OF MATURITY*

Another influencing BIM research and implementation framework has been proposed by Succar (2009). This has been widely referred and used by many works followed. He identifies three BIM maturity stages, and identifies Integrated Project Delivery (IPD) as the long-term goal after the third stage of BIM. Figure 2 presents the conceptual linear view of the maturity process.

The pre-BIM stage represents the conventional building practices, or the industry before the implementation of BIM. This stage includes both manual and computer based documents such as CAD drawings and spreadsheet schedules. Even 3D CAD is not considered as stage of maturity of BIM. Only object-based modelling and better is considered as BIM. Thus, Succar's model is comparatively stringent on the maturity level at the lower end.

Figure 2: BIM Maturity Stages – linear view by Succar (2009)

The pre-BIM stage would be characterized by 2D draughting, document-based linear workflows, asynchronous communication, and lack of interoperability (Khosrowshahi & Arayici, 2012). This stage may also include advance use of CAD such as 3D CAD. However, until and unless the modelling is object-based, it will not be considered as a BIM maturity phase.

The challenge a BIM infant industry like that of Sri Lanka would face is that the majority of organizations will not fall into any of BIM maturity level in either Bew-Richard or Succars models. Apparently, with their experience in the industry, authors are unaware of any organization falling into any BIM maturity level. In this context, a simple notion '*there is no maturity*' will not yield much help in terms of decision making on BIM adoption. On the other hand, it is questionable if such an industry should target first maturity level (*phase 1* or *stage 1* in above models) as the next step because there can be alternative roadmaps when well informed structural approach becomes possible. Therefore, an expanded framework for assessment is preferred. It should also be assured that the assessment framework enables comparison and contrasting of the current status with the ultimate BIM maturity level, so that it will help designing the BIM roadmap at industry or organization level.

2.3. *INTEGRATED DESIGN AND DELIVERY SOLUTIONS*

Reviewing the current applications and concepts of BIM, it was found that concept called *Integrated Design and Delivery Solutions* (IDDS) defines the ultimate maturity level of BIM. IDDS is one of the most comprehensive priority themes introduced by the International Council for Research and Innovation in Building and Construction (CIB). CIB describes, "*Integrated Design and Delivery Solutions use collaborative work processes and enhanced skills, with integrated data, information, and knowledge management to minimize structural and process inefficiencies and to enhance the value delivered during design, build, and operation, and across projects*" (Owen, 2009, p. 3).

IDDS is a holistic approach which effectively integrates people, processes and technology of the building industry. It is concept that has been developed on current technological advancement in the building industry fuelled by advancement of ICT, especially the BIM and related technologies, and novel processes like IPD. It aims to transform the construction sector through the rapid adoption of new processes, Building Information Modelling and automation technologies, using people with enhanced skills in more productive environments.

"*The development of IDDS is about radical and continuous improvement*" (Owen, 2009, p. 3). IDDS covers the current and future expectations thus becoming the ultimate mission of the building industry. It is a concept with a vision, and obviously a context that not yet has been achieved. In simple, IDDS is the BIM utopia, i.e. it is the perfect context that BIM can deliver best benefits. Thus, it is the ultimate maturity level of BIM implementation.

In 2010, Owen et al. (2010), with participation of BIM experts from around the world, reviewed the contemporary status of the building industry for its potentials to implement IDDS. They highlight the need to address improvements in terms of people, process and technology in parallel for better outcomes. IDDS is a holistic approach to get the maximum benefit of innovative technologies, especially BIM. They state that vital components are;

- Collaborative processes
- Enhanced skills
- Integrated information and automated systems, and
- Knowledge management

Classifying the BIM maturity status separately in each of these components will enable better comprehension on the status of a BIM infant industry. Since it is obvious that there are no actual BIM implementations in such an industry, the focus of assessment would be how strong its foundation is to implement BIM and reach IDDS stage in future.

3. BIM MATURITY ASSESSMENT FRAMEWORK

BIM maturity models are developed from observing the progression of industries which have already achieved certain BIM advancement. For a BIM infant industry, application of these BIM Maturity models to benchmark its maturity would reveal only little information. Absence of technology will allow higher flexibility for choices since decision is not influenced by the preference and learning curve of current users (as there is no one). This may also eliminate the requirement conventional maturity stages to be followed to reach the ultimate level. For the development of proposed maturity assessment framework, components of IDDS are used as the primary parameters. This assessment framework will allow well inform decisions on strategic BIM implementation. For example, an industry with better collaborations (non-BIM) has higher capacity to mature in BIM compare to a one with poor collaborations. A brief discussion on each four key elements of the framework follows.

3.1. COLLABORATIVE PROCESSES

Culture of distrust and litigation impedes collaboration in practice. Owen et al. (2010, p. 234) state that "in general, silo mentalities and cultures prevail and document-based information exchange across professions and throughout supply chains ensures that information and, particularly, any associated intelligence, coordination and agility is either corrupted or even lost. Thus decisions are frequently made autonomously without multidisciplinary participation, and in the absence of holistic or comprehensive and accurate knowledge. The use of an iteratively and incrementally developed design, pulled from an end user or client perspective, is virtually impossible within current structures, or at least rarely achieved." This description neatly explains the non-collaborative nature often found in the building industry. A paradigm shift is needed if the benefits of BIM to be achieved, or at least to prevent BIM implementation becoming a disaster. It should be noted that BIM relies heavily on power of computers to hold and process large amount of data which is shared among many project participants. Not like human brain, computers are less tolerant to erroneous and missing data and therefore would generate unexpected results if proper information is not provided on time by all participants.

Collaborative working in building industry has been encouraged for many decades. It is not a new concept even for a BIM infant industry. Prospects for collaborative procurement arrangements for Sri Lanka has previously being studied and has shown positive results than one could reason from the status quo (see Gunathilake & Jayasena, 2008). The study showed the change of attitudes and culture favourably to collaborative working once the context is purposefully changed. It showed collaborative working is hindered by procurement systems not supporting or promoting collaboration. Thus, mere observation of existence of collaborative processes will not offer full understanding; the framework should include an assessment of immediate potential for collaborative processes.

3.2. ENHANCED SKILLS

Integration skills are highlighted as important need. This does not refer to the skills of using BIM tools. It primarily refers to the abilities in parallel collaborative working. Owen et al. (2010) observed that in the contemporary building industry multi-tasking is rare and document based thinking is prevalent. A simplified example is Architectural drawings are awaited by the structural engineer to start structural design followed by HVAC engineer awaiting drawings from both for his design. In a multi-tasking setup, three designers would have worked in parallel, exchanging small portions of design developments by each of them in a collaborative work process.

The skill in using BIM tools relevant to the work performed by each professional or technical participant is also a necessity. The developments in the ICT industry and ventures of software developers have relieved most participants from knowing or becoming skilful in hardcore BIM technologies. Software tools are capable of processing and exchanging BIM data in background while providing user-friendly and familiar work interface for the user. A 3D graphical interface for Architects helps them to virtually model their imagination easily while the same model is shared with the Quantity Surveyor in 2D drawings and spreadsheet schedules for cost estimating. Thus, each participant is required to be skilful only in the tools used for his own performance. However, this does not relieve him from knowing what everybody else does in terms of delivery of the project, because that knowledge is crucial for collaborative working. A further limitation related to this is discussed in next subsection.

The skill in using relevant tools may offer further waivers. When CAD could not attract some of the professionals (for various reasons) when it started to become industry standard, it solved the problem by introducing a new technical layer of CAD draughtsmen to the industry. The same could be possible for BIM. Thus, multi-tasking will remain the primary skill enhancement required by the industry.

3.3. INTEGRATED INFORMATION AND AUTOMATED SYSTEMS

Owen *et al.* (2010) ascertained that integration is currently supported in BIM and associated tools. These are vendor specific and therefore tie only a small number of design and delivery tools; hence not capable of holistic integration. IFC standard offers interoperability but require individuals with special qualifications in each organization to ensure integrity of data exchange.

The future of integration sees that practitioners need not to understand the technology underneath but use tools to perform their respective tasks. An interoperability manager set up a framework for tools to seamlessly connect to each other to update the information required by any tool or process. Information integration should extend to the members of the value chain such as material suppliers and building operations (or facility management) teams. A study by van Berlo *et al.* (2012) has shown this is promising and authors believe this to be the highest practical proximity to true BIM as it has been conceptualized. Thus the ultimate level of assessment in terms of integration shall be set to van Berlo's model. An industry's ICT infrastructure shall be reviewed for its compliance to ultimate model.

In a BIM implementation, integration well supports and supported by automated systems. BIM and associated tools are regularly refined to improve their automation capabilities. In absence of BIM in a BIM infant industry, identical observations are not possible. However, other automated systems such as ERP (Enterprise Resource Planning) are positive signs of maturity.

3.4. KNOWLEDGE MANAGEMENT

Knowledge management (KM) has been popular research focus in recent years. Knowledge is thought to be the most strategically important resource for any company by many. Nevertheless, the fragmented, project-based and task-oriented nature of building construction work makes KM implementation difficult (Arayici *et al.,* 2011; Forcada, Fuertes, Gangolells, Casals, & Macarulla, 2013; Reginold, 2011). Knowledge management is currently at a poor state. “Codified knowledge within the typical firm exists within individual groups (discipline, trade, function) and is seldom shared with those in other domains or upstream or downstream partners in the name of ‘competitive advantage’” (Owen *et al.,* 2010, p. 238).

Knowledge management is generally not conceived to be directly related to BIM. One may assume knowledge management systems to be another branch of development in the building industry. It was however found that mainstream BIM implementation literature expressly or impliedly highlights the importance of KM. The need primarily arise from BIM’s lack of tolerance to erroneous or missing information. This demands project participants to provide timely and accurate information - a scenario which is easily perceived to be unrealistic. But, a proper KM system is capable of making it a reality. A proper system will not only harvest knowledge but also enable ongoing knowledge creation (Malhotra, 2004; Owen, 2009). It is important that KM system does not fail because its failure would also fail the whole BIM implementation.

Knowledge management does not show a strong position in Sri Lankan building industry (Senaratne & Sabesan, 2008) and it is unlikely to hold a good position in any BIM infant industry due to their lack of eagerness. This highlights the need of deeply assessing the KM maturity in a narrow spectrum. The primary measure would be to ascertain how well the current system (either purposeful or not) would map well with an appropriate automated system. Any current implementation of system would be considered as added maturity.

4. CONCLUSIONS

While implementation of BIM would probably pose numerous challenges, a BIM infant industry also benefits from option for wider number of potential alternative BIM adoption strategies. Thus, a coherent assessment of current context is crucial to chose most suitable strategies. The review of current knowledge showed that Bew-Richards BIM Maturity Model and Succar’s BIM Maturity Stages Model alone were less useful to assess a BIM infant industry. A framework of assessment had to feature in depth assessment of a narrow scope of earliest BIM maturity or immediate potential maturity at zero maturity.

The Integrated Design and Delivery Systems (IDDS), was found to be the definition of ultimate maturity level of BIM. It is therefore considered to be the final destination in a strategic BIM roadmap. Using the primary parameters of IDDS, a BIM maturity assessment framework is proposed. The framework comprises of four components.

1. collaborative processes: assessment of immediate potential for collaborative processes
2. enhanced skill: assessment of current status and immediate potential for multi-tasking
3. integrated information and automated systems: assessment of existing automated systems (nonBIM) and compatibility of ICT infrastructure for BIM integration
4. knowledge management: assessment of compatibility of current KM systems with the expected BIM enabled systems

The framework offers a guide for holistic assessment of BIM maturity in a BIM infant industry. However, in-depth study within each of above four components will be required to develop proper assessment criteria and tools. The framework can embrace both Bew-Richards BIM Maturity Model and Succar's BIM Maturity Stages Model for assessment at higher level of maturity. Logical decomposition and synthesising of the model to divide the model elements to four components of the framework would be challenging. If carefully done, the assessment tool so developed will become a valuable tool for all BIM infant building industries around the world.

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AUTOMATION OF BIM QUANTITY TAKE-OFF TO SUIT QS'S REQUIREMENTS

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ABSTRACT

Building Information Modelling (BIM) is a thriving technology which laid potential to address problems in conventional practices based on Computer-Aided Design (CAD) drawings. Sustainability and complexity of today's buildings are insist BIM technology and associated processes to develop for project delivery through sustainable procurement systems. Quantity Take-Off (QTO) is vitally important task in any building project since measurement practice applied to buildings has to be both accurate and consistent for auditing a building project from many different perspectives. However conventional QTO methods are tedious and error-prone. Major portion of Quantity Surveyor's time is spent for QTO. BIM QTO tools are task specific software applications delivering great promise to automate the extraction of quantities from BIM models. Visual building QTO improves productivity and accuracy that leads to sustainable QS practices. The time saving offered by these technologies will allow the Quantity Surveyor to focus more on other value adding services. However the automated outputs must suit the Quantity Surveyors' requirements in order to be effectively useful. Otherwise, the reliance on such technologies could result in such consequences, deviate from sustainability. This research is focused on "How far BIM QTO tools can automate QTO to suit QS's requirements?" The findings will contribute to the knowledge by establishing the status contribution of BIM for QTO being a primary function of Quantity Surveying within the overall sustainable procurement systems anticipated for the building industry.

Keywords: *Automation; Building Information Modelling (BIM); BIM Tools; New Rules of Measurement (NRM) Quantity Surveyor (QS); Quantity Take-Off (QTO).*

1. INTRODUCTION

Quantity Take-Off (QTO) is vitally important task in any construction project because of measurement practice applied to buildings has to be both accurate and consistent (Cartlidge, 2009). QTO is generally performed manually or using software packages from 2D or 3D Computer-Aided Design (CAD) drawings. BIM is gaining increasing acceptance in construction industry and utilisation of Building Information Modelling (BIM) make possible to considerably automate the QTO process using BIM QTO tools via model based quantity extraction techniques. There is a concern that BIM's capability to automate QTO will eliminate the need for Quantity Surveyor (QS) for this task. This paper presents a literature synthesis on "How far BIM QTO tools automate QTO to suit QS's requirements?"

2. BACKGROUND

Time, cost, and sustainability are of critical importance in today's construction market. In order to meet these constraints, designers require prompt feedback on the cost, schedule and environmental implications of their design decisions, and contractors need to find means to increase productivity on site. Current approaches that depend on 2D CAD drawings of a project are not adequate to meet these demands. The increasing complexity of buildings and requirement for more fast-track project delivery has made it more challenging to manage building information and deliver projects on time and under

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budget (Douglas, 2010). Building Information Modelling (BIM) is gaining popularity in the construction industry and holds great promise for addressing these challenges.

BIM is defined by the National BIM Standard (NBIMS) as “a digital representation of physical and functional characteristics of a facility” (National Institute of Building Sciences, 2007, p. 21). The concept of BIM is to build a building virtually, prior to building it physically, in order to work out problems, and simulate and analyse potential impacts. The heart of BIM is an authoritative BIM model (Smith, 2007).

Eastman, *et al.* (2011) defines BIM tool is a task-specific application that produces a specific outcome such as tools are those for model generation, drawing production, specification writing, cost estimation, clash and error detection, energy analysis, rendering, scheduling, and visualization. Tool output is often standalone, as reports, drawings, and so forth. In some cases, however, tool output is exported to other tool applications, such as QTO to cost estimation, and structural reactions fed to a connection-detailing application.

BIM QTO tools are QTO software applications that produce specific outcome for QTO by extracting necessary information from BIM models. All BIM QTO tools provide capabilities for extracting counts of components, area and volume of spaces and material quantities, from BIM models and to report these in various schedules (Eastman, *et al*., 2011). Therefore there is a potential that total QTO can be automated by using BIM QTO tools.

QTO is one of the most critical tasks concerned by all participants in the Architecture, Engineering, Construction and Facilities Management (AEC/FM) industry throughout the lifecycle of a building project (Zhiliang, *et al.,* 2010). The development of information technology in the AEC/FM industry has resulted in the emergence of numerous software applications for QTO. These achievements have greatly improved QSs’ working efficiency. However, in practice, when using the traditional two-dimensional representation of design, QSs still have to manually extract useful information from printed drawing sets or CAD drawings (Fortner, 2012). Due to the working complexity and comprehending deviation in these processes, QTO is still time-consuming and prone to error (Firat, *et al.,* 2010). Vico Software, Inc. (2013), Innovaya (2013), Tocoman (2013), Autodesk Inc. (2013), Buildsoft (2013), Nomitech (2013), Gala Construction Software (2013) and Digital Alchemy (2013) claims that the advent of BIM technology and their BIM QTO tools are potential solution for above problems.

High level of automation of QTO is possibly leads to no requirement of QS in QTO processes. Therefore dynamic and continuously updated BIM models itself may be enough to perform QTO automatically. However, if automated BIM QTO fails to fulfil the QS’s requirements to carry out his primary tasks like tendering and estimating, then such outputs may become less useful or even aggregate the current problems. Manual technical input will be required, but for that, it will be necessary to know for which items the manual input is required. Therefore for both the cases, there is a potential to research on level of automation in QTO by using BIM QTO tools. BIM revolution leads to be assumed BIM can fully automate QTO (Jernigan, 2008) and if that is not true, there is a risk that the process will result in less accurate estimate.

3. QUANTITY INFORMATION EXTRACTION REQUIREMENTS

There are a number of situations that require a QS to measure and record dimensions (or quantities) from both drawings as well as on site, depending on the stage of the project. In order to standardise measurement rules and conventions, there are a number of standard codes and methods of measurement available (Cartlidge, 2009). Quantities should be extracted from BIM models to suit QS’s requirements since extracted information serves wide scope applications such as pricing, cost modelling, estimating, and life cycle costing for various professionals like cost consultant’s and contractor’s QS.

Measuring construction works differently different parties was found to be a serious difficulty to contracting parties and a standing cause of disputes. For this reason a unification of the various systems at the technical level had been accepted as very desirable and wanting (Seeley, 1994). To cater this requirement Standard Methods of Measurement (SMMs) have been used such as Standard Methods of Measurement 7 (SMM7), Civil Engineering Standard Methods of Measurement 3 (CESMM3), New Rules of Measurement (NRM) and Sri Lanka Standard 573 (SLS573). SMMs provide a uniform basis for the measuring of works and embody the essentials of good practice, but more detailed information than is required by the standard shall be given where necessary in order to define the precise nature and extent of the required work (Wainwright & Whitrod, 1985).

SMMs were developed also to provide more consistency through providing guidelines on how the Bill of Quantities should be structured, which items should be measured, how they should be measured and what units should be used (Robin & Selwyn, 2012).

Further when doing QTO it is very important to measure the objects in the same way otherwise it will be difficult for other persons to get involved in the work or take over the tasks with the quantities. If for example the area of a wall has been calculated, it is essential to know whether the area includes door openings or not. Clear rules and norms are therefore essential (Eastman, *et al*., 2011). In this case SMMs vitality is experienced.

New Rules of Measurement - Detailed measurement for building works (NRM2) is the current SMM from Royal Institute of Chartered Surveyors (RICS) and effective from 1st January 2013. NRM2 provides a uniform basis for measuring and describing building works and embodies the essentials of good practice and replaces SMM7. Usage of each SMM is differs on scope of work and territories. For example, NRM2 and CESMM3 are used in United Kingdom (UK) for building works and civil works respectively and NRM2 and SLS573 are used for building works in UK and Sri Lanka respectively. In this research NRM2 is considered as definite requirement to quantity information extraction.

According to Tweeds (1995), Quantity Extraction falls into four continuous activities namely taking off, squaring, abstracting and billing. Quantity information extraction from BIM model is the first activity (i.e. take-off). Latter three activities can be found as derivation of the results of take-off since this research is targeted on how far quantity information can be automatically extracted from BIM models.

There are several rules set out in NRM2. For example for unit of measurement, common brick wall can be measured in m^2 but concrete wall can be measured in m^3. There are measurement rules, coverage rules, definition rules are governing requirements for QTO to suit NRM2 requirements. According to NRM2 there are three method of QTO are elemental, work section and work package (Royal Institute of Chartered Surveyors, 2013). According to organization preference any of the method is adopted. Anyhow traditional method is popular one. All these requirements eventually govern the standard and definite requirements to QTO.

4. BIM MODELS

Digital files are generated by all types of CAD systems. The older CAD applications employed only graphical information such as vectors, line-types to describe a building object. These systems where then developed to allow for more information to be added such as blocks of data and text. When 3D modelling begun to gain more popularity even more information could be added with complex surfacing and advanced definition tools (Eastman, *et al*., 2011).

With this development towards more information based drawings the focus changed from solely drawing and images towards the data itself. Today's BIM tools are object-based meaning that they show multiple views of the model in 2D and 3D as well as allows for properties to be stored within every single object. According to Eastman, *et al.* (2011), BIM is defined as:

> *"A modelling technology and associated set of processes to produce, communicate, and analyse building models."*

A building model is then characterized by:

- *Building components* - Represented by objects that "know" what they are and can be linked with data attributes, graphic and parametric rules. In this way a door will "know" that it is a door and that it can for example only be attached to a wall and not to a roof,
- *Consistent and non-redundant data* - a change made in one view will be represented in all other views as well,
- *Components* - include data that describe how they behave, for analyses and work processes, e.g. specifications, quantity take-offs and energy simulations,
- *Coordinated data* - all views will be represented in a coordinated way.

The main building product data model is the Industry Foundation Classes (IFC), for building planning, design, construction and management. IFC is the effort of building SMART whose goal is to specify a common language for technology to improve the communication, productivity, delivery time, cost, and quality throughout the design, construction and maintenance life cycle of buildings. Each specification (called a 'class') is used to describe a range of things that have common characteristics. These IFC-based objects aim to allow AEC/FM professionals to share a project model, while allowing each profession to define its own view of the objects contained within the model. The newer version of IFC is IFC4 published in 2013 as ISO 16739 (buildingSMART International Ltd., 2013).

The IFC is organized into sections that address different core areas and domain areas. These sections are organized into four layers, as shown in Figure 1 (buildingSMART International Ltd., 2013).

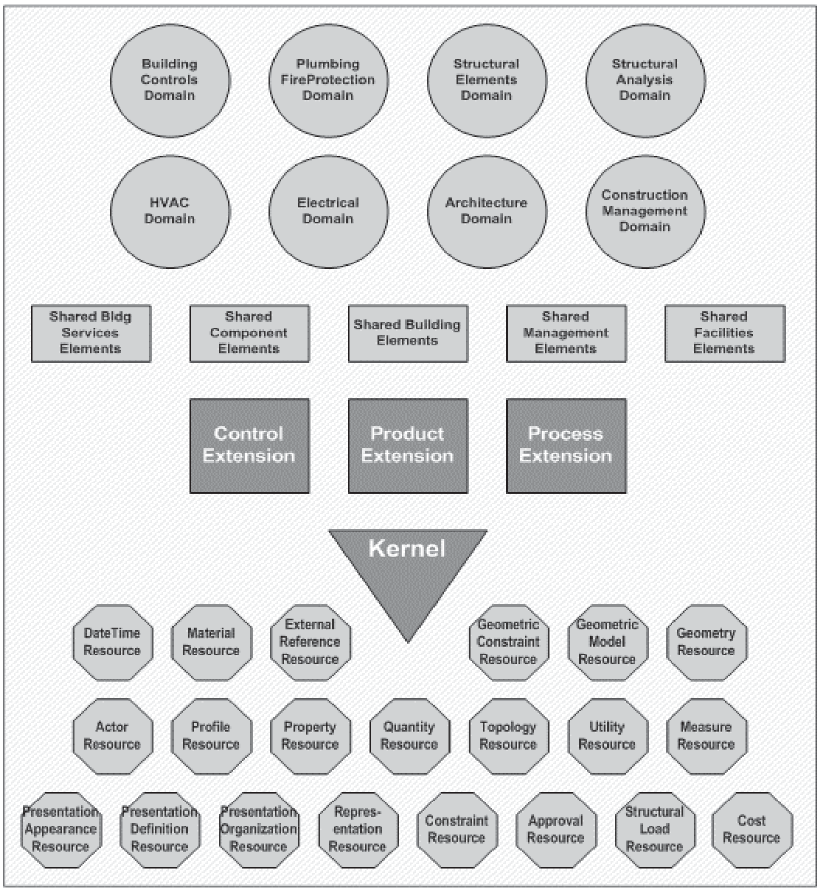

Figure 1: IFC4 Layered Structure (buildingSMART International Ltd., 2013)

The Resource Layer provides common resources used in defining the properties used by the upper layers. It includes Utility, Properties, Geometry, Measure and Property Type Resources. These provide geometric properties, units of measurement, cost units, time units and so forth. Those are standalone information required to information extraction.

Core Layer includes a Product Extension, Process Extension, Document Extension, Modelling Aid Extension and Kernel. The Product Extension supplies the majority of object classes making up the physical description of a building, defined at an abstract level. It includes generalizations for walls, floors and spaces, for example.

The Process Extension provides definitions of classes needed to represent the processes used to design and construct a building. The Modelling Aid Extension provides those abstract elements used in developing a building design, such as grids, modules and centrelines.

The Document Extension provides means to present project data in a particular format, useful for different needs in the building lifecycle. Future Core Extensions are planned for Controls and Resources.

The Kernel schema defines the most abstract part of the IFC architecture. It defines general constructs that are basic to object orientation, such as object and relationship. These are then specialized into constructs like product and process, which form the entry points of the next level, the Core Extension layer. The Kernel also handles some basic functionality, such as relative location of products in space, sequences of processes in time, or general-purpose grouping mechanisms which are important to QS.

The Interoperability Layer defines objects those are shared by more than one application. These objects specialize the Core Layer objects and elaborate them for use by applications. Currently the Interoperability Layer objects are primarily building elements and building service elements. Later, they are expected to include Distribution Elements (ducts and piping), Furniture, Electrical Appliance, and Building Codes.

The domain-specific application layer supports the applications used by QS. This layered architecture identifies the different resources and incremental abstractions needed forth definition of objects that carry data in a building product model (buildingSMART International Ltd., 2013).

5. BIM QUANTITY INFORMATION EXTRACTION METHODOLOGIES

The object model of the BIM is the logical data model that defines all entities, attributes and relationships in the BIM. The object model is physically implemented in the form of schemas. The model data is created by an application and stored in physical files or databases. The model data must be consistent with the object model of the BIM. The Standard for the Exchange of Product model data (STEP) covers the exchange of product model data. A STEP implementation is an application that uses this standard to exchange product information, or makes it possible for quantity information extraction applications to do so.

According to ISO 10303, STEP has four different implementation levels presented as (International Organization for Standardization, 2002):

1. *File exchange level*: Standard data modelling language for product data (EXPRESS)-defined product data is passed between applications using flat files. The STEP File part 21 and The STEP XML (Extensible Markup Language) Part 28 are the formats has been defined for this purpose and at this level for an application to simply read and write files. An application may read the EXPRESS-defined data file using a dedicated parser and immediately convert the instance data into some other data structure. Further XML files are capable of exchange through web based systems.
2. *Working form level*: The software in working form level has all features of level one in addition to the ability to manipulate data. When an application in this level reads the data into its memory the data should be made available to the code, in a form organised and described by the EXPRESS model. Standard Data Access Interface (SDAI) is developed as a standard API for level two. The SDAI functions allow the product data to be manipulated.

3. *Database level*: This level has all features of level two along with the ability to work with the data stored in a database.
4. *Knowledgebase level*: Implementations of this level will have all features of level three and should be able to reason about the contents of the database. This level has never been implemented.

It is possible to share and ex-change BIMs by using three implementation levels of STEP, if the model is defined by using STEP description methods. If not, then the BIM will possibly be defined and populated as a model in a relational or object database, and the data sharing will be realised by using the database interfaces. On the other hand, as the IFCXML implementation points out, the structure of the physical file will most probably be defined by using an XSD schema and the physical file will be exchanged as an XML file. There are five different methods for storage and exchange of BIMs (given in Figure 2– 6) that were identified through literature synthesis from various sources (buildingSMART International Ltd., 2012; Isikdag, *et al.*, 2007; Eastman, *et al.*, 2011; Eastman, *et al.*, 2012; Dimyadi, *et al.*, 2012; Kymmell, 2008).

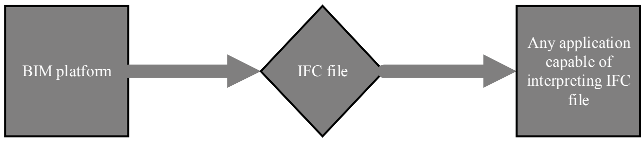

Figure 2: Data Exchange by Using Physical Files

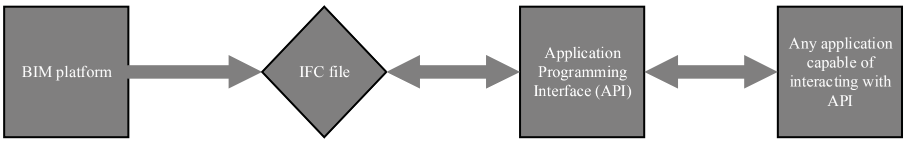

Figure 3: Data Sharing through Application Programming Interfaces

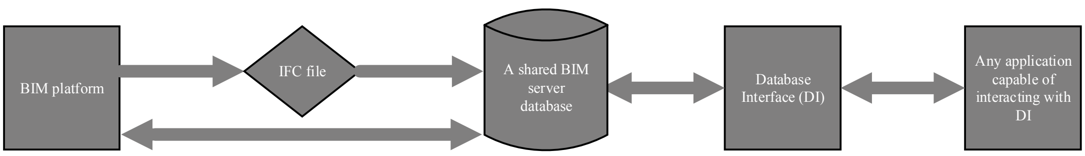

Figure 4: Data Sharing through Central Project Database

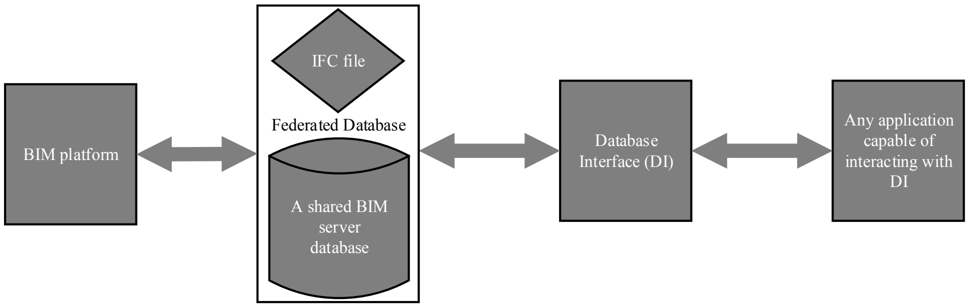

Figure 5: Data Sharing through Federated Project Database

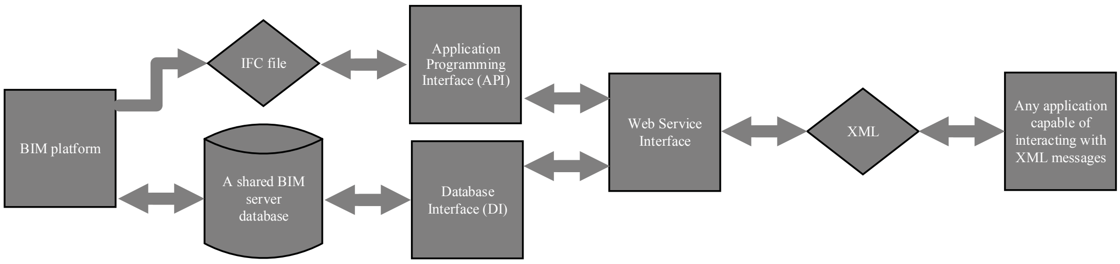

Figure 6: Data Sharing by Web Services

6. BIM QTO TOOLS

There are various open and proprietary BIM QTO tools available in the market. Most of them are intended to be capable of handle IFC files. IFC is supported by about 150 software applications worldwide to enable better work flows for the AEC industry (buildingSMART International Ltd., 2013). BIM QTO tools have the ability to extract required information from BIM platform like Revit and manipulate them within their API or derive information from BIM platform to them. Following are the notable BIM QTO tools:

- Innovaya Visual Quantity Takeoff
- Vico 3D BIM Quantity Takeoff
- Tocoman iLink
- Autodesk Quantity Takeoff
- CostX Takeoff
- Interactive Cost Estimating
- Buildsoft Takeoff 2
- CostOS BIM Estimating
- Gala Estimating
- IFC Takeoff for Microsoft Excel
- Smart BIM QTO
- ITALSOFT

Innovaya (Innovaya, LLC., 2013), Tocoman (TocoSoft Oy., 2010) and Vico (Vico Software, Inc., 2013) employ API to extract quantity information (Autodesk, Inc., 2006). This approach uses a direct link between the costing system and BIM platform like Revit. From within Revit, a user exports the building model using the QTO program's data format and sends it to the QS, who then opens it with the QTO solution to begin the QTO process.

CostX (Exactal Technologies Pty Ltd., 2010) and ITALSOFT use Open DataBase Connectivity (ODBC) connection (Autodesk, Inc., 2006). ODBC is a tried and true standard, useful for integrating data-centric applications like specification management and QTO with building information modelling. This approach typically uses the ODBC database to access the attribute information in the building model, and then uses exported 2D or 3D CAD files to access the dimensional data.

Quantity information extraction can be done within BIM platform like Revit and can be exported Output to Microsoft Excel (MS Excel). QTO can be done within Revit and output to a MS Excel program may seem lacklustre, but the simplicity and control is perfectly suited to some costing workflows. For instance, many firms just create material take-offs in Revit, output the data to a spreadsheet, and then hand it off to the cost estimator.

Vico 3D BIM Quantity Takeoff examines the BIM model geometry, applies special algorithms, and produces construction-calibre quantities (Vico Software, Inc., 2013). For example, Volume of the slab can be identified as a closed geometry with number of nodes within Vico environment. Surface area of slab can be identified from continuous loops of the faces that are identified from closed planes. When a slab is considered, edge surface area and plane surface area should be separately identified as per QS requirements. So different unique proprietary algorithms used by Vico to attain such (Vico Software, Inc., 2013).

Each QTO tool uses different extraction mechanisms; it is difficult to ascertain correct or wrong mechanisms (Autodesk, Inc., 2006).

7. CHALLENGES IN BIM QUANTITY INFORMATION EXTRACTION

As expected, attempting to automate the QTO process leads to some insights in the nature of the data itself .There are different components of quantity information need to be extracted from models as requirement of SMMs (Royal Institute of Chartered Surveyors, 2013). Those are:

- Items (counts),
- Linear (length),
- Surface (area),
- Mass (volume)
- Weight (in tonnes).

There are three kind of quantity information when we do QTO from the model. The rules that have been developed need to deal with kind of quantity information. The three types are (Bylund & Magnusson, 2012):

- Explicitly represented in the model,
- Components that are not explicitly represented but can be inferred,
- Components that are not represented in the model and cannot be inferred.

These obviously present a problem that cannot be resolved in taking models purely from BIM. The components that are represented explicitly need to be processed in two ways. Some components, such as doors and windows, just need to be counted. This requires simple query against the database. Other components need to be identified, have the length, area or volume determined, and then aggregated to the output. Discrete solid components, such as skirtings, floor finishes and concrete walls all fit in this group. NRM2 requires that the length of some components (e.g. precast units, Steel) to be included in the item description. For example manufacturer’s code, tonnage per meter or unit length should be included in description for structural steel. In this case, the presented quantity is in tones. The weight per meter of the member is required by QS. Eventually knowledge of the manufacturer’s products is required. This means item descriptions can be generated from following four stages - identify the relevant components, extract the required quantity, generate the item description and count the number of occurrences.

Vico claims that, With Vico Office, the QTO unique algorithm looks at each piece of geometry within the 3D BIM, calculates their properties (such as surface area, volume, etc.). The model geometry analysis algorithms can even determine the sides of the elements (for example "top of slab") and use the boundaries to calculate quantities such as "net surface area". This type of analysis is much more intuitive than simply counting windows and doors, floors, ceilings, and walls, and produces a much more detailed QTO. However, Vico deduced that "There Is No "Easy Button" for QTO in BIM" (Vico Software, Inc., 2013).

Sunny Choi claims that one of the challenges in extracting quantities is the requirement to follow the measurement rules SMMs and another challenge is different methods of building up BIM models will give out different quantities (Autodesk Inc., 2012). When different BIM applications are used in the project, not all software measures quantities in the same way. For example the length of a wall might be measured from the centreline or the outside resulting in a somewhat different area when calculated. Furthermore some applications gives the user the flexibility of modelling objects in different ways though quantification does not work with all of them. An example of this is when modelling openings using Revit. Openings could be modelled using an "opening tool", an "edit profile tool", an "opening family tool" or a "void extrusion". However the only way the opening gets quantified is if they are modelled using the opening tool or opening family tool (Tiwari, *et al.,* 2009).

8. BIM BASED QTO IN SRI LANKAN CONTEXT

BIM is still not implemented in Sri Lanka. Hence it's the big challenge to use BIM based QTO. There are several challenges for implementing BIM as well as using BIM based QTO. Shifting from CAD based current Sri Lankan construction industry to BIM based system need to lot of prerequisite like hardware, software and liveware alterations. Hardware includes system requirements to implement BIM and software includes the BIM platforms and other BIM tools and liveware includes construction industry professionals who need to have knowledge on BIM tools in their respective practices.

Still after implementing, interoperability and IFC supported BIM platform and BIM tools selection will only lead to successful quantity extraction. Except the challenges in implementing BIM, with in BIM based QTO, competency of professionals like QS are ultimate requirement to success.

9. CONCLUSIONS

Conclusions are derived on the basis of current literature synthesis since this is an ongoing research. QSs requirements are vital in QTO process in any scope of work or in any country. Quantity information must be extracted to suit QS requirements if BIM make any good to basic QS practices. Different components of quantity information should be able to be extracted by BIM QTO tools. Since identifying of objects counts is straight forward automated QTO will not be a problem for those items. Area measurement is likely to be most challenging and difficult to extract. Interoperability and retrieval mechanisms play vital role in QTO process and consistency in BIM modelling will ensure the reliability of QTO output. Ability to provide dynamic links within BIM data and BIM QTO tools will improve the reliability of QTO output. Bidirectional data retrieval methods will ensure consistency of the model with extracted quantities. Current developments in the BIM QTO automation are impressive, but there is no enough evidence concludes they can satisfy the needs of QSs QTO requirement. For QSs to receive true benefits from the developments in BIM, it is essential to clearly identify the QTO automation capabilities brought with them.

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BUILDING INFORMATION MODELLING AND FUTURE QUANTITY SURVEYOR'S PRACTICE IN SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

Sustainability has been an often mentioned goal of businesses, non-profit organizations and governments in the past decade, yet measuring the degree to which an organization is being sustainable or pursuing sustainable growth can be difficult. Building Information Modelling (BIM) is a new paradigm in the thriving Sustainable construction industry, from which the triple bottom line of the Sustainability can be greatly achieved. As the significance of BIM has become increasingly appreciated, most of the activities in the building industry have focused on BIM with sustainable design strategies. BIM has a great potential for integration into construction projects life cycle which will lead to pave the way towards becoming the industry standards for construction projects. Hence BIM would be a key tool in the project procurement in the future. However, BIM is not yet implemented in Sri Lankan construction industry where incorporation of BIM into construction projects life cycle would create differentiation in traditional procurement systems. Consequently, the role of Quantity Surveyors whose building procurement is based on BIM would be revolutionized drastically from the existing role where BIM permits to analyse the building, the structure, materials and performance in real time as it is being designed. Hence, a research is conducted with broader aim of exploring the potential expansions of QS roles, changing key roles and responsibilities of future Quantity Surveyors in a sustainable BIM based project delivery in Sri Lanka, which will lend a hand in training Quantity Surveyors to face future challenges. This paper contains the preliminary findings of a literature review conducted on the current key roles and responsibilities of Quantity Surveyors in local building procurement and future expectations in a BIM based project delivery.

Keywords: *Building Information Modelling; Quantity Surveying; Sri Lanka; Sustainability.*

1. INTRODUCTION

Building Information Modelling (BIM) is a new paradigm in the thriving Sustainable construction industry. BIM has a great potential for integration into construction projects life cycle which will lead to pave the way towards becoming the industry standards for construction projects and hence would be a key tool in the project procurement in the future. As a result, key roles of Quantity Surveyors (QS) in building procurement which is based on BIM would be quite different from today's roles. There are fears that adoption of BIM could threaten and challenge the existence of Quantity Surveying profession. There is a necessity to understand its potential expansions of QS roles in BIM based project delivery. Under this context, the work presented in this paper is a part of an on-going research which is conducted with broader aim of exploring the changing key roles and responsibilities of future Quantity Surveyors in a BIM based project delivery. While the ultimate findings of such a study will be helpful in training Quantity Surveyors to face future challenges, this paper presents literature synthesis of the same identifying the appropriate next steps to further the knowledge.

2. BACKGROUND

The construction industry is on the precipice of significant shift in the way that projects are executed. This shift promises to greatly improve the overall design and construction process. BIM and sustainable design construction are two important primary trends that are driving these changes in the industry (Johnson and Gunderson, 2009). Sustainable design is based on a number of factors, primary

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of which are climate, culture, place, building type and resources consumption. With the rising cost of energy and growing environmental concerns, the demand for sustainable buildings is growing day by day. Both public and private organizations are increasingly requiring architects and contractors to design and construct buildings with minimal environmental impact (Azhar and Brown, 2009). The most valuable decisions related to the sustainable design of a building can be made in the planning and design phases. As the significance of BIM has become increasingly appreciated, more activity in the building industry has focused on BIM and sustainable design strategies (Smith, 2007). Furthermore, Wong and Fan (2013) stated that it is believed that BIM is a critical element in reducing industry waste including wasted energy, adding value to industry products and decreasing environmental damage. According to Gleeson (2008) the combination of sustainable design strategies and BIM technology has the potential to change the traditional design practices, and produce a high-performance facility design. Therefore, there is a need for QS to get accustom to BIM based project delivery. This will pave the way towards the current Quantity Surveyors to become equipped with the necessary skills and competencies to ride the next global wave of sustainable development in order to remain in the forefront of the industry. The review follows first identifies the significant features of BIM and identifies their impact on QS roles.

3. BUILDING INFORMATION MODELLING

BIM is a new paradigm with the result of tremendous change for every professionals involved in the construction industry (Harris, 2011). BIM is not just software; it is both a technology and a process. The technology component of BIM helps project stakeholders to visualize what is to be built in a simulated environment to identify any potential design, construction or operational issues. The process component enables close collaboration and encourages integration of the roles of all stakeholders on a project (Azhar *et al*., 2012).

Several researchers have found that BIM is the process of creating a digital parametric model which represents the physical and functional characteristic of a building in full detail and further shared knowledge pool which can be used to form reliable decisions during the design, construction phases and throughout the life cycle of the facility (Eastman *et al.,* 2011; Suranga and Weddikkara, 2012). To create relationship between objects with in a virtual building model BIM uses parametric object modelling technology. These relationships include physical and functional characteristics as well as project life cycle information (Azhar *et al*., 2008). According to Wong and Fan (2013), BIM consists of information representing the entire building and the complete set of design documents stored in an integrated database. Hence it is clear that all the information is parametric and thereby interconnected. If any changes to an object within the model automatically it will affect the related assemblies and constructions. Furthermore, Jayasena and Weddikkara (2012) added that, BIM is not a software application. Instead it is an IT solution for integration of software applications and IT tools to design a building in a common platform, a platform which is independent of the software we use. Therefore BIM can be clearly differentiated from traditional Computer Aided Design (CAD).

3.1. CONVENTIONAL CAD AND NEW BIM APPROACH

BIM is a successor to the computer-aided drafting (CAD) was initially based on two dimensional drawings and lately on 3D views. However, these drawings lacked the interactivity and the change in one view was not automatically reflected in other views. With the advent of BIM, this practice has gradually started changing since the beginning of the 21st century. BIM based architectural software have allowed the automatic updating of views once the change is made in one view by the production of intelligent 3D/4D models. Besides the form (geometry), BIM is further meant for modelling the functions and behaviour of building systems and components (Sacks *et al.,* 2004).

BIM is gradually replacing the 2D or 3D CAD technology in many parts of the world. Although, most of these drawings can be prepared using conventional CAD software, BIM software produces these drawings more efficiently as part of the BIM and have the added advantage of parametric change technology, which coordinates changes and maintains consistency at all times (Azhar *et al*., 2010) The principal difference between BIM and 2D CAD is that the latter describes a building by 2D drawings such as plans, sections, and elevations. Editing one of these views requires that all other views must be checked and updated, an error-prone process that is one of the major causes of poor documentation today. In addition, the data in these 2D drawings are graphical entities only such as lines, arcs and circles, in contrast to the intelligent contextual semantic of BIM models, elements and systems such as spaces, walls, beams and piles (Ballesty, 2007).

3.2. BIM BASED PROJECT DELIVERY

BIM based project delivery can be known as the project which is based on BIM applications spans over the entire life cycle of a facility such as; project programming, design, preconstruction and post-construction phases. According to Autodesk (2013), the traditional 2D CAD-based design approaches focused on increasing the productivity of the construction document phase, a BIM-based design workflow changes the process in a more fundamental way by enabling the sharing and incremental enhancement of design information through all project phases. Following figures illustrate the development process traditional Design-Bid-Build Delivery System and BIM based delivery system.

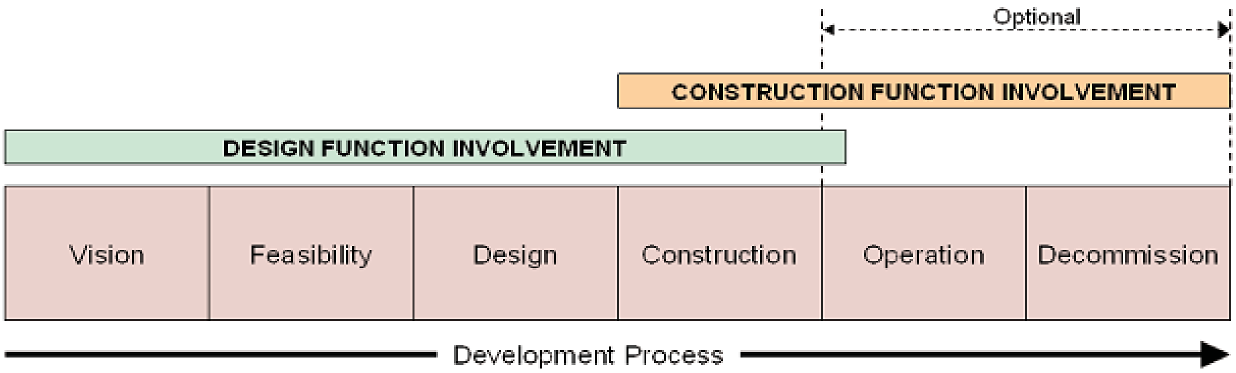

Figure 1: Design-Bid-Build Delivery System

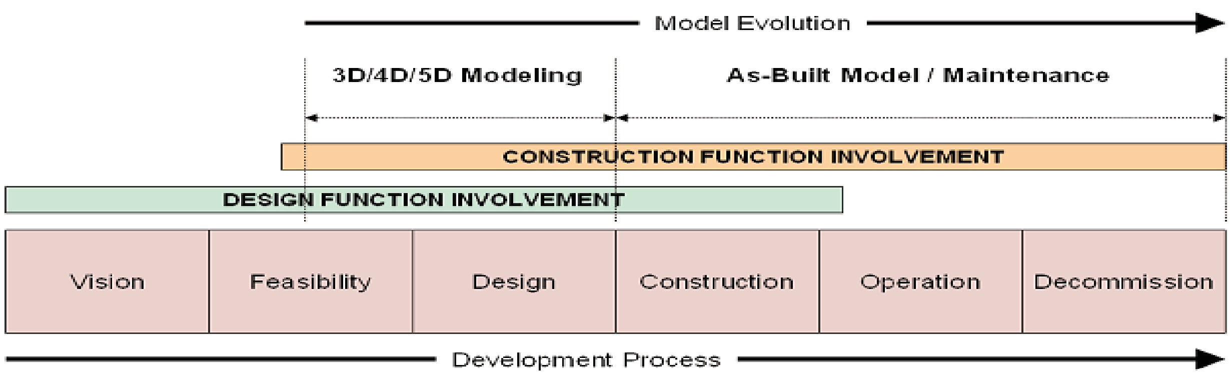

Figure 2: BIM Based Delivery System

The contrast of timeline interactions between design and construction functions in various project delivery systems are displayed in Figures 1 and 2. Figure 2 displays the involvement of the construction function stakeholder as early as the feasibility stage in BIM based project delivery which contains lot of benefits that identified by Ballesty, (2007) are listed below.

- Faster and more effective processes – information is more easily shared and can be value added and reused.
- Better design – building proposals can be rigorously analysed, simulations can be performed quickly and performance benchmarked, enabling improved and innovative solutions.
- Controlled whole life costs and environmental data – environmental performance is more predictable; lifecycle costs are understood.
- Better production quality – documentation output is flexible and exploits automation.
- Automated assembly – digital product data can be exploited in downstream processes and manufacturing. Better customer service – proposals are understood through accurate visualization.
- Lifecycle data – requirements, design, construction and operational information can be used for, for example, facilities management.
- Integration of planning and implementation processes – government, industry, and manufacturers have a common data protocol.
- Ultimately, a more effective and competitive industry and long-term sustainable regeneration projects.

Understanding about the BIM is compulsory for Quantity surveyor. Incorporation of BIM into the QS profession, leads Quantity Surveyor to perform their practices in a sustainable manner. The below sections are described how the BIM can be helped to perform cost management roles of quantity surveyor.

4. KEY ROLES OF QUANTITY SURVEYORS IN THE CONSTRUCTION INDUSTRY

Quantity surveyors are ubiquitous in the construction industry (Poon, 2003). According to a report published by RICS in 1971, the quantity surveyor's roll is "to ensure that the resources of the construction industry are utilized to the best advantage of society by providingthe financial management for projects and a cost consultancy service to the client and designer during the whole construction process". As we discussed earlier in introduction part, there are several roles which perform by the traditional QS. The key roles of a Quantity Surveyor are to perform financial control, cost and contractual administration of a project at every stage, from inception to completion. Table 4.1 most important Cost management roles of QS in the construction projects.

Table 4.1: Cost Management Roles of QS in the Construction Projects

Pre - Contract	**Post - Contract**
Preliminary cost estimating	Interim valuation and Payment
Procurement Advice	Final account preparation
Cost planning	Settlement of contractual disputes
Measurement of Quantities	Cost control during construction
Preparing Bills of Quantities	Analysis of Financial Risks
Bidding Process	Insurance Valuations

Source: (Willis *et al.,* 1994)

Quantity surveying is an essential part of the construction process, from project inception to building completion. It is a profession that necessitates both a high degree of knowledge and finely honed deployment skills. It entails accurate interpretation of designs and numerical representation of component quantities. Traditionally it is a manual process and such, is prone to errors as well as being very time consuming. However, time issues can be addressed and errors eradicated by automating the process BIM. Some cost management function of Quantity Surveyors are identified above table 4.1 briefly explained as follows.

Preliminary Cost Estimating

A process in which a BIM model can offer a reasonable accurate quantity take-off and cost estimate early in the design process and provide cost effects of additions and modifications with potential to save time and money and avoid budget overruns. This process allow designers to see the cost effects of their changes in a timely manner which can help curb excessive budget overruns due to project modifications. If the BIM model is shared with contractor, time for detail estimate can decrease dramatically and precision can go up (Colleen, 2009).

Procurement Advice

According to Boon (2009), for the potential of BIM to be realized, additional work early in the design process is necessary to set up the model and develop and analyses alternative design solutions. Adjustments to fees and timing of payments may be necessary to facilitate this. Similarly it is necessary to involve the contractor in virtual prototyping exercises for them to be meaningful. A procurement method that allows early contractor involvement is therefore necessary to realize this potential. Further, the use of BIM models that integrate the work of the architects, engineers in their many forms, contractor, subcontractors and suppliers creates new legal issues. Thompson and Miner (2006) identify the following:

- Who owns the BIM model and the intellectual property contained in it?
- Who controls the entry of data and who is responsible for inaccuracies?
- Who is responsible for the integration process and checking for dimensional coordination and clashes?

For quantity surveyors involved in providing procurement advice to clients these are issues they need to take account of and deal with in an arena where practice is rapidly evolving.

5D Cost Planning

Cost planning services that deliver cost certainty through realistic and precise cost estimates from inception to construction and at any point throughout all levels of development (Mitchell Brandtman, 2013). The broad objectives of cost planning are to ensure that the client receives an economical and efficient project in accordance with the agreed brief and budget, make the design process more efficient thus reducing the time needed to produce a successful design and, ensure that all work arising from the client's brief to the design team is included in the cost planning process. Specifically, cost planning is conducted to predict the contract sum by allocating cost targets to different parts of the building. It is also conducted to avoid abortive design work and provide a basis for cost control (Hua, 2010). Therefore, BIM provides facilities to quantity Surveyor to do cost plan automatically throughout the building elements.

Cost Estimating

Automated quantities generation provides a faster, more accurate tool to analyse data and provide better advice. This enables real-time options modelling and facilitates scenario testing to explore ways to improve building design, efficiency, performance and cost (Shaw, 2010). Quantity take-offs from a BIM model enable project teams to quickly generate cost estimates to assist in decision-making and provide cost information about alternatives to owners early in the design phase and throughout the project lifecycle. The BIM model is integrated with cost information from an estimating database, and this approach has proven to be quicker and reduces the possibility for errors and omissions. It can also reduce quantity take-off time and allow estimators to focus on higher value activities, such as identifying construction assemblies, generating pricing, and factoring risks (Autodesk, 2013).

Preparing Bills of Quantities

BIM is now liable for executing many traditional QS functions automatically with its 4D modelling capabilities. A BIM system can computerize the measurement of quantities from construction drawings. This will facilitate quantity surveyor to have design documents which include exact quantities and specified materials in electronic format. With the utilization of a correctly configured Building Information Model, a BOQ can be generated automatically. The BOQ is then applied to create reports in the essential format. This is performed with any phase of the QS dispatch ranging from estimating, tendering and construction control (BIM Outsourcing, 2013).

Bidding Process

Competitive tendering and bidding with BIM models can reduce the risky gap that exists between project members due to the transparency and accessibility to project information and documentation (Graham, 2010). In the Bidding stage, traditional tender process can be used for procurement. The BIM provided substantially higher quality construction information than conventional working drawings and provide a more accurate bill-of-quantities. In addition, potential constructors can receive training in quantity extraction and measurement from the BIM. During tender, bidders can identify and correct errors in the model, further enabling more accurate bids. The bidders could fully understand the building and their associated risk, which reduces the tender return prices (American Institute of Architect [AIA], 2008)

Cost Control

With the development of 3D building information modeling (BIM) combined withquantity information management, quantity and cost progress can be monitored and controlled in real-time, with accuracy and with transparency. Discrepancies, cost overflows and problems are seen earlier and steps can be taken to rectify them or at least minimize the consequences. The key issue is that quantity and cost information is monitored on as-it-happens basis and as-built quantity surveying is done in line with progress on site. Accurate quantity control can provide numerous benefits to the project as it is the basis for cost management, schedule management, procurement, logistics and resourcing. The more accuracy used and more importance given to it, the better the results: a better managed project (Gren, 2008).

4.1. Need of a QS to Get Accustom to BIM Based Project Delivery

Over budget, delays, rework, standing time, material waste, poor communication and conflict are the typical issues that have been faced by the today construction industry. With added pressures from the current global economic difficulties, the need to address and resolve these problems has never been greater. Key to tackling such widespread and internationally recognised woes could be through optimising building design information exchange efficiency and accuracy with a view to creating great certainty in delivery of construction projects. Therefore, the intelligent BIM may offer a solution to above deficiencies (Hooper, 2012).

Furthermore, Owners are often faced with cost overruns or unexpected costs that force them to either “value engineer or Quantity Surveyor” go over budget, or cancel the project. To mitigate the risk of overruns and unreliable estimates, owners and service providers add contingencies to estimates or a budget set aside to cope with uncertainties during construction (Touran, 2003).Unreliable estimates expose owners to significant risk and artificially increase all project costs. The reliability of cost estimates is impacted by a number of factors, including market conditions that change over time, the time between estimate and execution, design changes, and quality issues (Jackson, 2002).The accurate and computable nature of BIM provides a more reliable source for owners to perform quantity take-off and estimating provides faster cost feedback on design changes. This important because of the ability to influence cost is highest early in the process at the conceptual and preliminary phase (Eastman, *et al.,* 2008). Furthermore, quantity surveyors cite insufficient time, poor documentation and communication breakdowns between projects participants, especially between client and QS, as the primary causes of poor estimates (Akintoye and Fitzgerald, 2000).

Several researchers evaluated that reasons for adoption of BIM in to the Quantity Surveying profession are as follows (Thomas, 2010);

- 30% of projects do not meet original programme or budget
- 92% of clients said that designer's drawings are typically not sufficient for construction
- 37% of materials used in construction become waste
- 10% of the cost of a project is typically due to change orders
- 38% of carbon emissions are from buildings not cars

This brings forth the argument that as BIM reduces the resources needed for a construction project and costs are saved on the reduction of resource, professional fees needs to be adjusted downward (Gee, 2010). Today, use of BIM is typically limited to the late phase of design and engineering or early phases of construction. Use of BIM earlier in the design process will have greater influence on cost. Improving overall cost reliability is a key motivator for employing BIM based cost estimating methods (Eastman *et al.,* 2008).

Considering the current academic research, in professional development and industrial market, BIM is being considered highly significant to the future development of construction information technologies and to the construction industry (Azhar and Brown, 2009). Further, BIM has emerged as an innovative way to manage projects. BIM accelerates collaboration within project teams, which will lead to improved profitability, reduced costs, better time management and improved customer/client relationships (Azhar *et al*., 2010). Therefore, there should be the needs for QS to get accustom to BIM based project delivery.

4.2. CHALLENGES OF BIM

A major challenge is that most design firms are hesitant to practice on real projects. Therefore, they often set up a BIM group and let BIM guys work in parallel with the project's teams. As a result, the project will have a BIM model but the project's team will have had very limited exposure to BIM. Worse yet, this practice will often bring more costs to the project, since the BIM teams' efforts will add extra cost and may not contribute much savings (Wang, 2012). Some problems with BIM highlighted by Howell and Batcheler (2004) include:

- BIM systems create big and complex files hence the scalability and manageability of a fully loaded central BIM project database becomes a major challenge.
- Sharing BIM information as drawing files. Users are defaulting back to exchanging documents (drawing files created as views of a building model) rather than sharing intelligent objects from the model.
- The need for increasingly sophisticated data management at the building objects level. Pioneering model server technology is only now being developed to help address issues which surface when multi-disciplinary design teams try to adopt a single BIM such as object versioning, object-level locking and real-time, multiuser access.
- A contradiction in work process when using a single detailed BIM to try to represent a number of the alternative design schemes under consideration. While parametrically defined building objects can quickly be recreated based on the input of selected dimensions and properties, the need to maintain separate BIM models for different design alternatives is prohibitive
- Every company on the project team cannot adopt one BIM system. Each company normally has its own preferred and trusted software applications for design and analysis. It is very rare that a single technology is being used on any one building project between different companies and across all phases of the project lifecycle rather than being dependent on a single building model, project team members typically rely on a number of purpose-built models.

4.3. INFLUENCE OF BIM AND EFFECT TOWARDS QS ROLES

Traditionally quantity surveyors fulfilled the role of measuring and valuing construction works. With the deterioration of this role, quantity surveyors have been evolving and adapting their services that have led them to become professional experts on the contractual and financial aspects of construction developments and the management there of (Ballesty, 2007). The changing role of the quantity surveyor lies in the ability to remain key advisors on the financial and contractual decisions on construction developments. Quantity surveyors need to keep reinventing themselves and continually add value and enhance their professional services (Ashworth and Hogg, 2007; Sutrisna *et al*., (2005) specified that, Conventional construction estimating practices have been criticized as there is hardly an estimate without its own peculiarities and current estimating processes are seen by some as too rigid. BIM remains a nascent ideal whose realization is probably many years off. However, the rewards are high as the time taken to measure buildings will be markedly reduced, leaving more time for estimating calculations (Olatunji *et al*., 2010). Masidah and Rashid, (2005) argued that, measurement and pricing of construction works are important functions provided by Quantity Surveyors. This is central to the contention that BIM's potential to automate quantity measurement might threaten clients' requirements for quantity surveying services. BIM is a major challenge to the services conventionally provided by quantity surveyors and other construction disciplines. The adoption of BIM may redefine traditional professional boundaries in construction (Olatunji *et al*., 2010). Following are some of the barriers and risks identified for the QS profession with incorporation of BIM.

4.3.1. SOFTWARE AND COMPUTER SYSTEMS

Regardless of the many limitations of the collaborative capabilities of software supporting the traditional methods for developing construction products, most professionals prefer such system due to the traditional approach to 'software implementation' enables the systems to be user-friendly. Further, they offer a gradual change to using automated systems and most systems present data in traditional paper format such as take-off paper (Matipa, 2008). However, Current systems seem to be working well, yet they severely impact on the pace at which the quantity surveyor performs his responsibilities at the design stage of the construction project (Matipa, 2008). Cost estimates are prone to contain various inaccuracies as they are usually based on limited information and prepared within a limited time frame (Aibinu and Pasco, 2008). In an ideal BIM environment, first step would be the design of a 3D model of the client's proposal and the second will be to automatically generate resource demands, cost calculations or estimates, list of product specifications and bills of quantities (Popov *et al*., 2009). This requires the extraction of all dimensions and information on building components from the 3D model and then combining it with databases containing unit costs and other data (Bazjanac, 2010).

4.3.2. ADJUSTING SERVICES AND RESPONSIBILITIES

Traditionally, when the design of the proposed project is at a point where it can almost be frozen, the Quantity Surveyor starts to prepare bills of quantities and other documentation that can support the procurement process. Estimating in the design phase is usually conceptual and is based on limited project information, with the consequence that Quantity Surveyors are more involved in the latter part of the design appraisal process (Matipa, 2008).

The automation of bills of quantities reduces error and misunderstanding and evolves in step with the design changes (Ashcraft, 2007). It removes some of the tedium and speeds up the process (Ashworth and Hogg, 2007). This leaves more time for analysis, interpretation and organization of data into a logical, consistent and cognizant format, and shifts the traditional role of costing a design to designing to a cost (Matipa, 2008). Designing to a cost satisfies the demand for 'value for money' and therefore fulfils one of the cardinal responsibilities of the quantity surveyor (Petric and Maver, 2003). However, prevention of inaccuracies of data re-entry and ensure consistency between models creates the need for an individual to manage the data exchanged between consultants.

4.3.3. TRAINING AND EXPENSES

The development of new technology and the implementation of new methods and tools usually go hand in hand with multiple expenses and a lack of knowledge and skill relating to the technology. The transition phase from traditional methods to new generation, BIM technology will not come without the necessary challenges. The lack of knowledge and skill relating to sophisticated software and techniques are usually easily over come through training programs, seminars workshops and software tutorials (Rundell, 2010).

4.3.4. PREREQUISITES FOR QUANTITY SURVEYORS

New skills will be required by project team in order to use BIM with significant outcomes and fee scales will need to be adjusted in order to commensurate with professional responsibilities (Olatunji and Sher, 2010). RICS (1971) emphasized that the distinctive competencies or skills of the Quantity Surveyor are associated with measurement and valuation which provide the basis for the proper cost management of the construction project in the context of forecasting, analysing, planning, controlling and accounting.

5. CONCLUSIONS

BIM is a major challenge to the services conventionally provided by Quantity Surveyors and other construction disciplines. BIM is a development aimed at integrating working systems and adding value to building economics and project delivery (Matipa, 2008). It offers to remove routine and drudgery from many activities and produce high standard results (Ashworth and Hogg, 2007). Quantity surveyors are still relaying on the production of bills of quantities to feature as their main line of business, this is reducing substantially due to the automation of this task (Matipa, 2008). The changing role of the quantity surveyor lies in the ability to remain key advisors on the financial and contractual decisions on construction developments (Ashworth and Hogg, 2007). Quantity surveyors that are able to overcome these challenges will secure their future in the technologically developing industry. Therefore they need to focus on enhancing the learning experience on BIM technology and collaboration techniques, updating industry methods and techniques and development of QS specific skills such as visualisation (3d viewing), quantification, and data scheduling and pricing and finally multi-disciplinary work based projects. In order to understand the future role of QS into further detail, a thorough study on what specific information will be made available for him from BIM at different stage of the project and what information the QS has to contribute at each stage is required. This is identified as the way forward for the current study.

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COMMON ERRORS THAT ARE BEING MADE IN PREPARING AND PRICING BOQ IN SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

In construction projects the Bill of Quantities (BOQ) has become a vital document in post contract stage as well as in pre contract stage, since the BOQ address the important three aspects of a project, that are time, cost and quality. Therefore, it is necessary to illustrate that if there is any error in BOQ that would directly affect the base of the construction projects. As a result, all stakeholders involved in a project have an extremely higher concern on those three aspects, as having an error free BOQ is vitally important. Errors can occur during preparation stage and pricing stage of the BOQ. Further, to minimize BOQ errors it is important to have a clear understanding on the errors which occur most frequently during preparing and pricing stages of a BOQ. Therefore, this research study is focused to identify the common errors that are being made in preparing BOQ in Sri Lankan construction industry. A literature survey was carried out to identify the importance and common errors of BOQ during preparation and pricing BOQ in construction industry and this paper presented the findings of it. The survey revealed the importance of BOQ in post contract stage as well as in pre contract stage. Moreover this research has identified the errors which occurred during preparation and pricing stages of BOQ separately, and the reasons for those errors. This would then lead to establish a mechanism to, either to eradicate or minimize errors in BOQ preparation and pricing within the construction industry and hence facilitate to sustain the BOQ as an important and reliable document in the industry.

Keywords: *Bill of Quantities (BOQ); Cost; Errors; Quality; Time.*

1. INTRODUCTION

Since the involvements of stakeholders are high in the construction industry, in order to carry out the construction in an effective manner, certain documents are required to be included in the contract document. Out of those binding documents a Bill of Quantities (BOQ) is a critically important document (Lee, *et al.,* 2005).Traditionally Consultant is deemed to be the responsible person for the preparation of BOQ and prospective contractors should price it. However a priced BOQ represents merely an estimate therefore it should be to minimize the discrepancy between estimate and the actual cost (Lee, *et al.,* 2005). Further Davis, *et al.* (2009) revealed that there is a possible reluctance to use BOQ as part of the contract, because of the client's sensitivity to the claimed disadvantages, rather than advantages of BOQ. Therefore, BOQ should not have errors in description, quantities or with pricing which leads to substantial disputes regarding time, cost, and quality. In order to prevent those errors within the construction industry standards were developed and practiced in order to take off measurements (Lee, *et al.,* 2005).

Irrespective of the usage of standard methods of measurement certain errors are still available, and that would lead to many critical consequences. Client's main requirements and concerns are whether the project completed on time, within the estimated cost and within specified quality (Rashid, *et al.,* 2006). Moreover if the BOQ errors lead to time, cost and quality issues of projects it may affect to the sustainability of the practice of BOQ in the industry. Furthermore, Jaffar *et al.* (2011) have identified errors substantial changes in bills of quantities as a source of conflict in construction.

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2. IMPORTANCE AND USES OF BOQ IN CONSTRUCTION

According to Millican (1996 cited in Bandi, 2012) BOQ is a document used over 300 years as a one form. Further it is a critically important document in construction industry particularly under the traditional procurement method. Seeley (1997 cited in Davis *et al.,* 2009) stated that absence of a BOQ may lead to greater variability, increased risk in estimating and consequently more disputes. Based on the arrangement of Hackett, Robinson and Chan (2003 cited in Rashid, *et al*., 2006), it can be illustrated that BOQ is a document specifying the qualitative and quantitative aspects of each and every essential parts of a proposed construction project.

Brook (1998 cited in Davis*, et al.*, 2009) illustrated that the BOQ has two primary uses in pre contract and post contract stages. In pre contract stage, BOQ assists contractors in the formulation of tender document, through breaking down the contract works in a formal, detailed, and structured manner for tendering (Australian Institute of Quantity Surveyors). Moreover, in post contract stage the BOQ assists contractor and Quantity Surveyor (QS) in preparation of interim payments and valuing variations, as well as it provides a financial structure for contract administration (AIQS, 2001 cited in Davis*, et al.*, 2009). Hence according to Rashid *et al.* (2006) BOQ is a multipurpose document. Furthermore BOQ can be seen, as a source of valuable information for not only the management of project cost but also the management of the project, because project cost management is an integral part of project management which strike a balance between competing demands among cost, time, quality and scope of a project (Rashid *et al*., 2006)

However according to Molloy, Willis and Turner later it came to know that BOQ has its own uses at pre contract stage as well as in post contract stage (Rashid *et al.,* 2006).

2.1. IMPORTANCE OF BOQ IN PRE-CONTRACT STAGE

BOQ preparation is an activity performed during the pre contract stage. In traditional procurement the consultant is deem to be responsible to prepare the BOQ. Further according to Millikan (1996 cited in Davis *et. al.,* 2009) errors in BOQ preparation stage may lead to various problems which would place a havoc in post contract stage.

Importance and the use of BOQ in the pre contract stage for many construction stake holders have been identified by many researches. In a nutshell these facts are identified and illustrated in Table 1 as follows;

Table 1: Importance/Use of BOQ in Pre Contract Stage

Importance / Use	For Whom	Source
Give sense of control of projects, in term of cost and finance	Architects and other consultants	Rashid *et al.,* 2006
As part of the Tender document for requesting competitive tenders from contractors	Consultant QS on behalf of the Client	Rashid *et al.,* 2006
Price the work on precisely the same basis, thus allowing for the fairest bidding	Contractor	Rashid *et al.,* 2006
Assessing Tenders	Consultant QS on behalf of the Client	Rashid *et al.,* 2006
Asset Management	Client	Davis *et al.,* 2009
Consultant's fee calculation	Consultant and Client	Davis *et al.,* 2009
For Projecting Cash flow and Budgeting	Contractor and Client	Rashid *et al.,* 2006
Work items and the quantities in the BOQ can be convert to a detail Work Breakdown Structure (WBS) of the project (for Project Planning)	Contractor	Rashid *et al.,* 2006 Adnan et al., 2011

2.2. *IN POST CONTRACT STAGE*

Since the origin of the BOQ, its functions and use has remained same over the past without major changes. Even at present BOQ is still considered as a document for project costing and as part of tender document to obtain and assess competitive tenders from contractors. Bearing that fact in mind it is necessary to identify the other important features and uses to the stakeholders with in the construction industry. Therefore, Table 2 clearly emphasised the essence in BOQ as identify by many researches.

Table 2: Importance/Use of BOQ in Post Contract Stage

Importance / Use	For Whom	Source
BOQ serves as a post-contract administration tool and becomes a basis for the evaluation of progress payments.	Client, Consultant and Contractor	Davis *et al.,* 2009 Adnan *et al*., 2011
BOQ provides a proper, common basis for the valuation of variations	Contractor and consultant	Cartlidge, 2009 Davis *et al.,* 2009
The prices in the BOQ are a basis for comparing a contractor's price with current trends in the market. This provides a basis for management to determine the likely causes of risk factors	Consultant and client	Davis *et al.,* 2009
Preparing Material Schedule and for Material reconciliation	Contractor	Wainwright & Whitrod (1980 cited in Rashid *et al.*, 2006) Adnan *et al.*, 2011
Preparation of Final Accounts	Contractor and Consultant	Rashid *et al.*, 2006 Adnan *et al.*, 2011
Procure Sub contractors	Contractor	Rashid *et al.*, 2006 Adnan *et al.*, 2011
Effective and efficient project management (and site management)	Contractor and Consultant	Rashid *et al.,* 2006 Adnan *et al.*, 2011
Act as a legal document	Contractor and Client	Kodikara *et al.* (1993 cited in Adnan *et al.,* 2011)

Accordingly BOQ can be considered as a vitally important document in the construction industry which has become complimentary for key stakeholders as well as minor stakeholders in the industry.

3. BOQ PREPARATION

In traditional BOQ preparation can be divided in to two distinct stages as follows (Lee *et al.*, 2005);

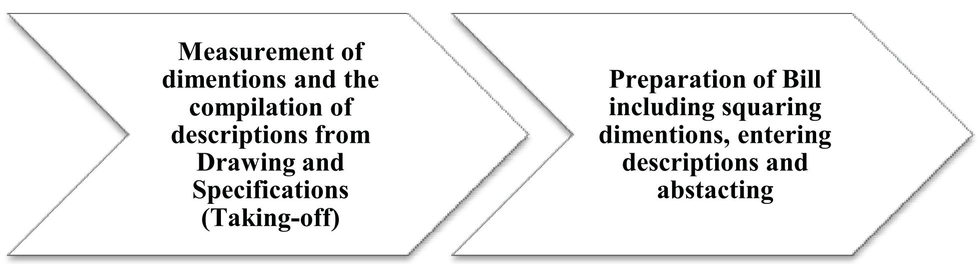

Figure 1: Stages of BOQ Preparation

In the process of preparing BOQ it is necessary to carry act a thorough examination on the design and specification. This process enables the QS to identify inaccuracies and inconsistencies in drawings and specification prior to tender, and to reduce subsequent problems in post-contract stage (Milliken 1996 cited in Davis *et al.,* 2009). Due to the fact that BOQ form a part of contract, accuracy of the bill preparation has become more important. Moreover if there are substantial errors it will lead to form a contract which involved a sum considerably beyond the consideration. Hence to mitigate errors and discrepancies QSs use standard methods of measurements when preparing BOQ, so that contractors can identify how quantities have been prepared and including and excluding of each and every item in the bill (Lee *et al.*, 2005).

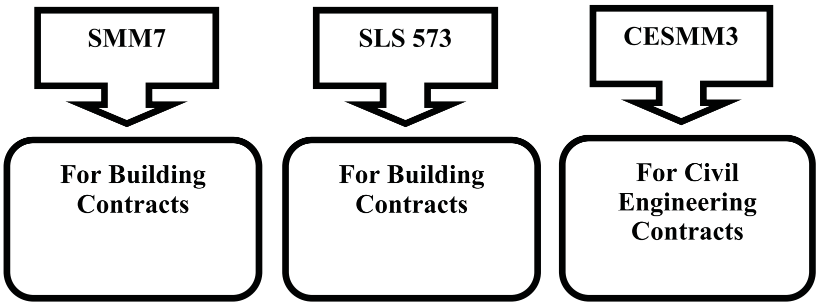

Figure 2: Standard Documents Used for Bill Preparation in Sri Lanka

However, in Sri Lanka consultants also use its own method of measurements to prepare BOQs and it may cause increase many of errors in preparation stage as well as in pricing stage, than using any standard method. Further, Perera *et al.* (2003) have identified opinions of consultants and contractors on reluctance in usage of standard method of measurements in Sri Lanka. The factors identified in the research by Perera, *et al*. (2003) clearly denoted the main reasons as illustrated in Table 3.

Table 3: Reluctant to Usage of Standard Method of Measurement (Perera *et al.,* 2003)

Consultant's Perspective	Contractor's perspective
Drawings are not prepared in detail at the time of preparation of BQs. Thus detailed itemization is not possible.	Lack of resources in estimating staff, time constraints within which tenders should be Submitted etc.
Standards lack clarity to a larger extent and the Quantity Surveyor is left with no assistance to solve such matters.	The cost information available for the contractors is not updated frequently and may not be suitable for accurate estimating.
Consultants have observed that contractors do not consider the relationships between items of work. Same costs are included in different items resulting in higher tender prices. This is because contractors are more familiar with all inclusive prices, and even when items have been separately identified they tend to price as usual ignoring the detailed itemization.	The contractors have not classified their overhead expenses and project costs to a sufficiently accurate and organized method.
Consultants sometimes lack experienced Quantity Surveyors competent enough to follow the SMM. Often the case is that there are lot of people who have emerged to the QS profession with their experience in the industry and not with adequate theoretical background. It is difficult for them to switch from their traditional ad-hoc practices to new standards that have been developed.	
The time available to prepare a BOQ is sometimes very short that detailed items cannot be measured.	

3.1. BOQ PREPARATION ERRORS

A standard method of measurement provides a uniform basis for measurement which leads to easy preparation of BOQ due to less complexity for the contractor. Further this is due to the fact that easier identification of cost in a significant and methodical manner. Moreover BOQ preparation errors will have effect on cost, since BOQ contains the cost deciding factors for the project (Perere, *et al.,* 2003). Irrespective of the usage of standard methods of measurement certain errors are still available. However, that would lead to many critical consequences. Improperly prepared BOQ may lead to greater variability, increased risk in estimating and consequently more disputes (Seeley, 1997). Therefore it is considerably important to have proper monitoring in both taking off and bill preparation stages since errors can happen during both stages.

Quantity is an important element in a BOQ; according to Adnan *et al.* (2011) providing in accurate quantity is a deficiency of a BOQ. Further Adnan *et al.* (2011) stated that because of this reason contractor price items like preliminaries at a higher cost to preventthe loss that the contractor might realized after winning the bid and when the contract is in process. Tharindu (2012) also has identified incorrect quantities as a problem of the BOQ. Include irrelevant preliminary items under preliminary bill can be identified as another error or deficiency of a BOQ, which can happen due to usage of preliminary items of another projects which are not in same scope and same nature, without doing any adjustments. Similarly same discrepancy might occur with standard specifications used in BOQ due to the same reason as in preliminary (Adnan *et al.,* 2011). Adnan *et al.,* (2011), & Tharindu, (2012) has identified insufficient information in description such as not mentioning the location, as another error of BOQ preparation. This would later become a plague for both pricing and quantifying. Further Adnan *et al.* (2011) emphasized that temporary works which are not a part of final product, would have less specification and work method leading to price with high allowances which increase the final contract sum and decrease the competitiveness of the bid. Hence this also can be identified as an error of a BOQ (Adnan *et al.,* 2011). Davis *et al.,* (2009), and Thrindu (2012) has identified omissions and discrepancies between drawings and BOQ as another error in BOQ preparation. This can happen due to the usage of out dated drawings and carelessness of the taker off. Further this would lead to under measurement, omitted items and mis-described items as stated by the New South Wales Public Works Department (1992 cited in Davis *et al.,* 2009).

Today, more often software packages are used to prepare BOQ, with its own format for inputting dimensions and formulating descriptions. However, a thorough knowledge of measurement conventions is essential in order to fully understand and appreciate the probable problems in the measurement process (Cartlidge, 2009). Therefore the usage of software packages also may lead to errors other than the above mentioned factors. Further it was explained that when two or more QSs involved in preparing a BOQ for same projects there may be omissions of some items and quantities, as well there may be double counting of items.

Further there are many errors in BOQ preparation which are identified through many research expertises. These errors are illustrated in Table 4 as follows.

Table 4: Identified Errors of BOQ Preparation

Errors	Source
In correct Quantities	Adnan *et al.*, 2011, Tharindu, 2012 Cartlidge, 2009
Including Irrelevant Preliminary items.	Adnan *et al.*, 2011
Including unnecessary specifications.	Adnan *et al.*, 2011
In sufficient information with descriptions.	Adnan *et al.*, 2011, Tharindu, 2012
Tender BOQ is invariably silent about the actual items of temporary works.	Adnan *et al.*, 2011
Omissions and miss discrepancies between drawings and the BOQ.	Davis *et al.,* 2009, Tharindu, 2012

4. BOQ PRICING

BOQ facilitate detail basis for estimating the cost for contractors. Furtherspecification of the contract document, demonstrate quality and types of materials that must be priced for and used by the contractor (Cartlidge, 2009). Cartlidge (2009) stated that a unit rate prepared by the contractor should include some or all of following;

- Labour costs – the all-in labour rate. This is built up from operatives' wages plus statutory costs such as national insurance, etc.
- Material costs – the basic costs of materials plus the costs of delivery, unloading and storage and allowances for wastage
- Plant costs – the hire cost of mechanical plant plus delivery to site, operating costs (drivers and fuel), etc. Can be included in the preliminaries section, under the appropriate clause
- Overheads and profit – overheads are such items as head office costs. The profit margin will vary according to a number of external factors, including risk. Surprisingly, in the UK the profit margin for many general contractors is low. The contractor may choose to include overheads and profit in the individual unit rates or make suitable allowances elsewhere in the tender.

The total of all the BOQ amounts finally provide the estimated tender sum (later become the contract sum). According to the Sinclair, *et al.,* (2002) an estimate always attempted to target, the actual cost. Therefore an estimate should be prepared carefully without errors, with the intention that contractors have to price the BOQ properly with having minimum errors.

4.1. PRICING ERRORS

When pricing a BOQ errors can happen generally irrespective of the knowledge and experience of the estimator (Hurd, 2007). Errors which are performed during pricing of tender may cause to have unrealistic rate and it will finally cause to lose the tender or if win to have poor quality output. Therefore it is of greater importance to prepare an error less estimate to have confident on profit as well as competitiveness (Hurd, 2007). Further Hurd (2007) stated that an error free estimate is better for both client and contractor since construction cost estimate is vitally important for both.

In order to prepare an error less estimate Sinclair *et al*. (2002) identify factors to be considered which are listed as follows;

- Work method is a very important component of pricing and therefore disregarding all possible work methods for selecting most economical solution can be identified kind of error.
- Assume past performance will be repeated in future; this will cause to reduce contractors' profit or reduce the competitiveness of the tender.
- Labour charges may change according to different factors such as location difficulty of work, regulation, market conditions. Therefore, when pricing disregarding those factors and assume a constant rate become an error. Therkildsen (2012) also has stated under estimating labour cost as a mistake.
- Disregarding the material wastage factor according to the nature of work, because wastage factor may vary on location, work method.

Sinclair *et al.* (2002) also has identified that with the estimators experience and education level the degree of error can vary and with the time and manpower allocated for estimation the accuracy may also be varied. Further, Therkildsen (2012) stated estimating mistakes or error, as follows.

- Doing changes to the prices at last minute is very often. This may cause to have simple mistakes such as calculation or formula errors which can quickly convert a profitable project in to a loss.

- A company may have different expertise in several areas, therefore in estimating they will focus on those specific areas only, hence the possibility of having errors in areas which have not expertise with in the company become high.

To reduce perishing every contractor must have a clear tendering policy, lack of one may become an error for the estimation (Cartlidge, 2009). As specified in Davis *et al.* (2009) pricing based on BOQ description without considering specification can be identified as an error which later leads to an under estimate and further affect to the quality since contractors do not want to lose own money. According to Seeley and Winfield (1999 cited in Odeyinka, *et al.,* 2009) contractors increase the rate to cover the risk of pricing errors due to not utilizing in the field as well. Further, still there are arithmetic errors despite of the usage of calculators and other software (Hurd, 2007). There are certain other pricing errors as well. These are identified in Table 5.

Table 5: BOQ pricing Errors

Errors	Source
Careless consideration of Work method	Sinclair *et al.*, 2002
Assume output of a crew based on past performance	Sinclair *et al.*, 2002
Decide labour payments disregarding changing factors	Sinclair *et al.*, 2002, Therkildsen, 2012
Consideration of finished in place quantity of material	Sinclair *et al.*, 2002
Estimators experiences and education level	Sinclair *et al.*, 2002
Not having clear policy regarding tendering policy	Cartlidge, 2009
Ignore the Specifications and pricing according to the BOQ description	Davis *et al.,* 2009
Increasing rates to cover the increased risk which is taken by not using a quantity surveyor to price the projects	Seeley and Winfield (1999 cited in Odeyinka, 2009)
Ignorance of relationships between items of work. Same costs are included in different items resulting in higher tender prices.	Perera *et al.,* 2003
Lack of transparency of the estimation	Therkildsen, 2012
Last minute changes	Therkildsen, 2012
Focusing on items, which estimator is more expertise	Therkildsen, 2012
Pursuing every project	Therkildsen, 2012
Allocating resources incorrectly for the project	Therkildsen, 2012
Not taking a top-down approach for pricing	Therkildsen, 2012
Lack of successive risk estimation	Therkildsen, 2012
Wrong assumptions regarding items in the BOQ	BuildingAdvisor, 2012
Arithmetic errors of the estimating despite of the usage of calculators and other software	Hurd, 2007

5. CONCLUSIONS

BOQ is an important document within the construction industry, especially under the traditional procurement method. However there is a decline of using BOQ in near past and it may cause to the sustainability of the BOQ as a financial decision make tool within the construction industry. Literature confirmed that despite of the decline of usage, BOQ has its own important uses during the post contract as well as during the pre contract stages. Further literature express that there are errors in preparation and pricing of BOQ and those errors may lead to underestimate the use of BOQ in the industry since those may affect to the accuracy and the confident of the users. Therefore, it is recommended to investigate further about those identified and unidentified errors to increase the reliability upon BOQ and hence try to sustain the BOQ with in the construction industry further as a good financial decision making tool.

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COMPARATIVE EFFECTIVENESS OF QUANTITY SURVEYING IN A BUILDING INFORMATION MODELLING IMPLEMENTATION

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ABSTRACT

Over the past eras, growths of innovative technological concepts are promptly increasing, in order to achieve competitive productivity and performance. Building industry identifies technology as vital. Although the building industry is broadly identified as unique and conservative, at the same time construction industry has to have varied according to these innovative technological variations. In addition to that these technological variations may have potential to influence everyone's professions in different ways. Although, the concept of Building Information Modelling (BIM) is not practiced in Sri Lankan construction industry yet, it is likely to become the project delivery standard in future. Introduce with the vision "sustainability by building smarter", BIM will improve the performance of building professionals. The current knowledge does not adequately explain how the functions of a Quantity Surveyor are affected by BIM. This paper presents a study on comparative effectiveness offered by BIM for the traditional functions of a Quantity Surveyor. The study is interesting because the new knowledge will help to develop strategies for professional development and update the education curricula to train the Quantity Surveyors to face future challenges.

Keywords: *Building Industry; Building Information Modelling; BIM; Quantity Surveying; Sri Lanka.*

1. INTRODUCTION

As the world is transforming and developing at a very express pace, rapid technological innovative practices are increasing, in order to achieve the competitive advantage. Building Information Modelling (BIM) is one of innovative practice which is becoming a better known established collaboration process in the construction industry. This study explores how the practices of Quantity Surveyors are being influenced by BIM and comparative effectiveness of BIM tools against conventional Quantity Surveying methods.

2. INTRODUCTION TO QUANTITY SURVEYING

A Quantity Surveyor is an expert in the art of costing a building at all its stages who offer expert advices on construction costs. It is inevitable that, the advices are vital for life cycle costing, cost planning, procurement and tendering, contract administration and commercial management. Moreover, a Quantity Surveyor may be involved as a specialist in one area or generalize in several over the course of a project (RICS, 2012) and he known as a Construction Economist, a Cost Manager, a team of professional advisers to the construction industry as well. As advisers they estimate and monitor construction costs, from the feasibility stage of a project through to the completion of the construction period. After construction they may be involved with tax depreciation schedules, replacement cost estimation for insurance purposes and, if necessary, mediation and arbitration (AIQS, 2011).

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2.1. *HISTORY OF QUANTITY SURVEYING PROFESSION*

Eventhough ancient Egyptians are believed to be amongst the first ones to have practiced a system of Quantity Surveying, it was not until the 17th century restoration of London after the Great Fire that Quantity Surveyors developed as an occupation (AIQS, 2011). In 1834 architects decided that they wished to divorce themselves from surveyors and establish the Royal Institute of British Architects (RIBA), exclusively for architects (Cartlidge, 2009). The grounds for this great schism were that architects wished to distance themselves from surveyors and their perceived 'obnoxious commercial interest in construction'. The events of 1834 were further responsible for the birth of another UK phenomenon, the Quantity Surveyor. A study by Ashworth and Hogg (2007 as cited Shangvi, 2012) emphasized that Quantity surveyors trace their roots back to more than 2000 years ago. However, the fire that destroyed the Palace of Westminster in 1834 is considered to be partly responsible for the employment of the QS on an extensive scale. Around 1820, quantity surveying was imaged as a profession and Sir Henry Arthur Hunt is considered as one of the earliest Quantity Surveyor, who involved in the construction of House of Parliament in United Kingdom (Quantity Surveying Practices, 2012).

2.2. *ROLE OF A QUANTITY SURVEYOR*

Quantity surveying is an important discipline within the construction industry. Matipa (2008 as cited Gee, 2010) proved that the Quantity Surveyor is responsible for the management of costs through the whole of the project and is involved from the feasibility and design stage up to the completion of the project and can have responsibilities such as calculating replacement cost or estimation for insurance purposes after construction. Ashworth and Hogg (2007 as cited Fanous, 2012) concluded that traditionally Quantity Surveyors are expected to conduct initial cost planning, measure and quantify all elements of a project, control costs throughout construction, give procurement advice and prepare financial documents, accounts and valuations. This is known as a simple 'measure and value' system and still remains the main, if not only, purpose of modern quantity surveyors working on smaller projects. Olatunji *et al.* (2009) discussed that the majority of the most important functions traditionally carried out by quantity surveyors are based upon the measuring and pricing of construction works. Following is the representation of the 9 most important traditional roles and responsibilities of a Quantity Surveyor identified by Fanous (2012) in his empirical study.

- Providing Approximate Cost Estimates
- Advice on Procurement
- Cost Planning
- Measuring Items on Site
- Preparing Bills of Quantities
- Preparing Schedules of Works
- Preparing Financial Statements
- Controlling Costs throughout Project
- Assessing and Negotiating Tenders

Furthermore, Olatunji *et al.* (2009) spotout that Quantity Surveyors are ubiquitous in the construction industry. Conventionally, Quantity Surveyors' services include the preparation of preliminary estimates and feasibility studies bills, Quantity surveyors draft and compile documentation for construction contracts. They further provide advice on contractor selection and financial management of all construction works and allied reporting, including auditing, planning cost and indexing. They provide construction project management services as well as value management, facilities management, management contracting, construction dispute resolution, research, and other forms of consultancy services. A recent article of AIQS (2011) indicates that preparing bill of quantities (BOQ) is one of the oldest tasks performed by the Quantity Surveyor. In fact, the Quantity Surveyors get their name from the BOQ. Furthermore Shangvi (2012) denote that, a comparison of the prices quoted in the BOQ normally forms the basis of selection of a tender, especially, on the traditional design-bid-build route. The process of measuring quantities of various items of work is termed as quantity takeoff.

Preparing preliminary estimates is one of the important traditional tasks which are performed by Quantity Surveyor. A study of Ashworth (2010) emphasized that preparing pre-tender estimates or cost estimates provides an indication of the probable construction cost which is prepared at various stages of the project like the conceptual stage and the detailed design stage. Fiserv (2012 as cited in Shangvi, 2012) show that cost reporting is again different from cost planning and cost estimating. It is an exercise whereby the QS provide regular updates on the likely out-turn cost of a project. According to Shangvi (2012) the contractor's Quantity Surveyor prepares payment applications, usually on a monthly basis, which contain a statement of monies due to the contractor by the client based on the progress of works.

Value Management and Life Cycle Costing are relatively new concepts compared to the other traditional tasks outlined above. However they have greater relevance in present times to the Quantity Surveying profession. Cartlidge (2008 as cited Shangvi, 2012) states that Value Management (VM) is concerned with enhancing the performance of a building at the same cost or achieves the same functions at a lower cost. A recent article of Isurv (2011) declared that Life Cycle Costing is a decision-making technique that takes into account both initial and future costs over the life of a building. For buildings and structures, it is inevitable that, not only capital costs, the relevant costs in use or operational costs will consider as well.

3. INTRODUCTION TO BIM

Building Information Modeling (BIM) has recently attained widespread attention in the Architectural, Engineering and Construction (AEC) industry. BIM represents the development and use of computer generated n-dimensional (n-D) models to simulate the planning, design, construction and operation a facility. It helps Architects, Engineers and Constructors to visualize what is to be built in simulated environment and to identify potential design, construction or operational problem (Azhar*et al*., 2010). Furthermore Smith (2007) says, the concept of Building Information Modelling is to build a building virtually prior to building it physically, in order to work out problems and simulate and analyse potential impacts.

Succar (2008) defines, Building Information Modelling (BIM) as a "set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle".

3.1. THE HISTORY OF BIM

Before 1980s traditionally, Architecture, Engineering, Construction industry used to express building components in symbolic language and orthographic drawings by means of manually drafted drawings on paper using drawing boards, T-squares and pencils. With the development of the computer science, in the early 1980s, architects began using geometry-based CAD (Woo, 2007). BIM is a three letter acronym, Building, Information, Modelling coined by architect and Autodesk building industry strategist Phil Bernstein in 2002 who used the actual terms for BIM (Beck, 2008). However, according to Eastman (1999 as cited Fanous, 2006) state that BIM concept can be tracked back 30 years ago and credited to Chuck Eastman, who created it at the Georgia Tech College of Architecture and computing which he referred to as "Building product model". Eastman described Building product model as "the provision of rich, integrated information from conception through design to construction and demolition of a building over its life cycle".

BIM has brought a new era for the construction industry and there is a little disagreement that BIM is a new era and will transform almost everyone in the building and construction industry (Neeley, 2010).

3.2. CAPABILITIES OF BIM

Building Information Modelling (BIM) is the latest technology in the built environment utilising data models. It is a multi-dimensional model that acts as a communication and information resource over the lifecycle of a construction project (Gee, 2010). Olutanji *et al.* (2009) says relevant literature highlights BIM as three- or four-dimensional drafting applications that generate data-intensive plans. In contrast to two dimensional drawings where sets of lines and surface areas are rendered through soft and hard intelligent features, BIM systems store data related to each 'object'. The implication of this on the construction process is that construction designers and constructors are able to model real life situations before moving to site. Muzvimwe (2011 as cited Shangvi, 2012) summarise that following BIM applications which are capable to provide the services on a construction project.

Table 1: BIM Applications which are Capable to Provide the Services on a Construction Project

3D BIM (Design)	They can create three dimensional (3D) models of the buildings from which the design can be visualised at any stage of the project. Moreover, 3D models are useful for design coordination and clash detection of services in a building.
4D BIM (Scheduling)	Certain BIM applications possess the capability of linking the components of the model to the construction schedule. This process of adding the parameter of time to the 3D model is termed as 4D simulation. The 4D model is used for planning and tracking construction activities.
5D BIM (Cost)	The 5D model is an integration of design (3D) and schedule (4D) with the costs associated with the components of the model. It is primarily used for cost estimation.
6D and 7D BIM	Due to the large scale research and development, the repertoire of BIM tools now covers applications related to life cycle management and sustainable design which are referred to as 6D and 7D.

4. BUILDING INFORMATION MODELLING AND QUANTITY SURVEYING PRACTICE

4.1. IMPACT OF BIM ON QUANTITY SURVEYING PROFESSION

Technology is developing rapidly by improving all its subsectors across the world and making all the real life functions easier than they were. The construction industry which identifies technology as vital, has been sensitive to these technological changes. Ashworth and Hogg (2007 as cited Gee, 2010) emphasized that the Quantity Surveying profession is, like many other professions, an evolving profession that needs to continue to change to meet the ever changing conditions of the building industry. The history of Quantity Surveying and the way Quantity Surveying tasks were performed provides enough substantial evidence to show how Information Technology has changed the way Quantity Surveyors perform their duties and the speed and efficiency of the professional services of the Quantity Surveyor.

BIM has the potential to influence every characteristic of the construction industry together with construction professionals. BIM consists of 3-dimensional design functions (3D), programming and scheduling functions (4D) and cost estimating functions (5D). Olatunji *et al.* (2009) specified that, BIM is a major challenge to the services conventionally provided by Quantity Surveyors and other construction disciplines. The adoption of BIM may redefine traditional professional boundaries in construction not just for Quantity Surveying. BIM has the potential to automate measurement and facilitate the preparation of accurate estimates. Building Information Modeling has the capability to automate a quantity take-off, which will reduce the time and costs required to estimate a project; however, the industry is not using BIM for estimating. BIM software is compatible with estimating software, such as Innovaya Composer, which converts BIM files, making them compatible with Timberline's estimate and quantity data (Sattineni and Bradford, 2012). According to Gee (2010), BIM's capabilities of automating the production of bills of quantities, which is one of the Quantity

Surveyors fundamental tasks, will have both positive and negative effects on the Quantity Surveying industry. Hergunsel (2011) reported that two main elements of a cost estimate are quantity take-off and pricing. Quantities from a Building Information Model can be extracted to a cost database or an excel file. However, pricing cannot be attained from the model. Cost estimating requires the expertise of the cost estimator to analyse the components of a material and how they get installed. If the pricing for a certain activity is not available in the database, cost estimator may need a further breakdown of the element for more accurate pricing. Autodesk (2007) argues that as BIM tools are capable of automating the tedious task of quantifying, they allow the estimators to dedicate their valuable time on other cost sensitive tasks as pricing and factoring risks. Baldwin and Jellings (2009) emphasized that traditionally followed Quantity Takeoff and bill generation is a very time consuming process that are prone to error. Moreover, it is perceived that the following factors undermine the accuracy of the manual Quantity Takeoff.

- Errors associated with moving data between files
- Risk of double counting
- Risk of missing elements
- Multiple 2D drawings themselves are likely to contain many errors compounding the problem further

Furthermore Paul *et al.* (2011) denote that BIM software can help assist the Quantity Surveyor in various tasks rather than quantification. BIM can aid programme certainty at tender stage, contractors can link their programme to the model upon tender submission, and this should reduce the amount of variations required during the construction phase.

As a summary it can be illustrated that there is considerable impact of BIM on the profession of Quantity Surveying.

4.2. USAGE OF BIM AS A QUANTITY SURVEYING TOOL

The use of Building Information Modelling (BIM) in the construction industry is on the rise. It is widely acknowledged that adoption of BIM would cause a seismic shift in the business processes within the construction industry and related fields (Sattineni and Bradford, 2012). The manual process requires a great deal of time for revising the BOQ to accommodate design changes. Hence, the BOQ is often out-of-date. Ashworth (2010) considers that the speed of response and the ability to reduce manual errors have led to the wide spread use of software applications for performing QTO and estimating. The 5D model created by BIM has the potential to perform an automatic analysis of all materials and components and to derive their quantities directly from the model (Baldwin and Jellings, 2009). Eastman *et al*. (2008), consider that proponents of BIM are very useful for VM as the speed of response of BIM tools provides an excellent opportunity to perform VM throughout the design period.

Baldwin and Jellings (2009) reported that Consolidated ContractorsCompany used BIM to generate bulky monthly payment applications, cost reports and estimated that by utilizing BIM in the Dubai Mall project. That tasks which would possibly have required 25 full time QSs were carried out by employing 8 modellers and 2 BIM engineers. BIM suggest that a detailed building model wouldprovide a greater certainty over the quantities of material, andtherefore, BIM would produce a more reliable cost estimate comparedto the traditional process (Eastman *et al*., 2011). Monswhite (2011 as cited in Shangvi, 2012) denote that large clients who have their in-house cost database can directly derive their estimates during the early stages of the project using BIM based estimating tools such as DProfiler. Therefore, they can afford to do without the services of the QS.

According to Eastman *et al.* (2011 as cited in Shangvi, 2012), below table provides an overview of the capabilities of BIM applications pertaining to the traditional quantity surveying tasks.

Table 2: Capabilities of BIM Applications Pertaining to the Traditional Quantity Surveying Tasks

Traditional Quantity Surveying task	**BIM tools capable of performing that task**
Quantity Take-off	Autodesk QTO, BIM Measure fromCauseway
BOQ Preparation	CostOSTM, Nomitech
Cost Estimation	DProfiler, Beck Technology
Cost Planning	Vico Cost Planner
Cost Reporting	Vico Office Client
Cost Control	Vico Cost Explorer
MaterialProcurement	Quantities of material can beobtained using BIM tools for QTO
PaymentApplications	Bentley
VM	BIM tools for estimating can beused to obtain the estimated costs of various design options
Life Cycle Costing	Integrated Environmental Solutions Virtual Environment

4.3. UNCERTAINTY OF BIM AS A QUANTITY SURVEYING TOOL

Building Information Modelling "BIM" is becoming a better known established collaboration process in the construction industry (Hergunsel, 2011). However, as per the viewpoints of Ogunsemi *et al.* (2010), there is a second line of thought within the construction industry which suggests that, BIM is not completely trustworthy as a Quantity Surveying tool as nonconformity of the output data from BIM with the standard methods of measurement. Furthermore Buckley (2008 as cited in Shangvi, 2012) argued that, BIM tools are not advanced enough to be capable to substitute the experience and expertise of the QS. Furthermore Bruce Buckley does not endorse this practice of preparing a cost estimate without the involvement of an estimator and estimator's knowledge and experience are absolutely essential to adjust the estimate in accordance with the specific conditions of a project. Moreover Buckley point out that BIM tools are not programmed to perform such adjustments by themselves. Olatunji *et al*. (2010) have doubts over the reliability of QTO performed by BIM applications as BIM tools simply provide theoretical quantities based on the attributes of the model without any allowances for wastage, lapping etc.

5. CONCLUSIONS AND WAY FORWARD

Technology is developing rapidly by improving all its subsectors across the world and making all the real life functions easier than they were. The construction industry which identifies technology as vital has been sensitive to these technological changes. According to the literature, Building Information Modelling (BIM) is one of the technologies that have been creating a buzz in the construction industry over the last few years which have potential to effect of Quantity Surveying profession. However, the technology itself provide list of benefits as well as a certain degree of risk which depend on the situation its being used.

The review of current knowledge synthesized numerous benefits of BIM for QSs to offer effective service. Finding the validity of these conclusions empirically will be the next step of this study. However, in the absence of real cases of proper use of BIM in Sri Lanka, a positivists approach is not possible. Thus, the research will involve triangulation and interpretation of information from multiple sources to draw sensible conclusions.

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COMPARATIVE STUDY OF GREEN BUILDING RATING SYSTEMS: IN TERMS OF WATER EFFICIENCY AND CONSERVATION

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ABSTRACT

The construction industry puts a great effort on achieving sustainable development. This is because in the construction industry a lot of natural resources are being consumed. Water is one of the most important natural resources for the development of all economic activities taking place to care for the environment and quality of life in the society. Therefore, availability and management of water resources is essential for a long term sustainability of any country. At present, many environmental assessment tools or green building rating systems developed and accepted by many countries. Simply, green building rating systems provide best standards and assist to fulfil green building practices. Each rating system addressed key sustainable parameters: energy, water, site, indoor environmental quality and materials in order to build sustainable environment.

Since freshwater scarcity has become a global issue, this paper aims to investigate how and in what strategies water efficiency and conservation is discussed in the existing green building rating systems. Primarily, literature review and documentary review were used as the main research method. The eleven green building rating systems which are designed for new construction were considered and were analysed to compare in terms of the key requirements/strategies and credits awarded for water efficiency and conservation in the rating systems. It was found that in terms of water, intention of each rating system is to reduce potable water consumption compared to the benchmark buildings. It further address in many directions to conserve and monitor water throughout the project life cycle. However, few rating systems have only addressed water conservation and water pollution during the construction phase. Furthermore, the paper enables to analyse the priority given for the water efficiency compared to other sustainable parameters.

Keywords: *Construction Industry; Green Rating Systems; Sustainable Development; Water Efficiency and Conservation.*

1. INTRODUCTION

The concern for environment and sustainable development is being increased in world wide. From this dimension, there has been a rapid development in the number of environmental or green building assessment methods, tools, and certificates especially under the popular buzz words ‘sustainability’ and ‘green’. Boonstra and Pettersen (2003) emphasized the requirement of environmental assessment methods which respond to environmental issues and define sustainable levels. According to Hiete *et al.,* (2011), various building rating systems make use of hierarchical criteria systems to evaluate the buildings with respect to the different aspects of sustainability. Fowler and Rauch (2006) explained that sustainable building rating systems are used to examine the performance or expected performance of a ‘whole building’ and translate performance assessment into a tool that can be used to compare the building performance of other buildings or a performance standard. As stated by Gowri (2004), green building design challenges to go beyond the typical building code requirements to improve overall building performance and minimize life-cycle environmental impact and cost. Cole *et al,* (n.d.) mentioned that motivates change in the construction industry and market transformation by attaching a label of environmental performance that increases the real market value of buildings improving

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environmental qualities. Moreover, Sev (2009a) recognized, building environmental assessment tools have become widespread in recent years and attracted the construction sector and public awareness in sustainability. Therefore, at present, construction industry is one of the industries talk more on sustainable and environmental performance. Thus, use of environmental tools to measure project performance becomes a compulsory item in industry stakeholders' project agenda.

As revealed in literature, environmental assessment systems or tools (Boonstra and Pettersen, 2003; Cole et al.,n.d), building environmental assessment tools (Sev, 2009a; Wallhegan, 2013); sustainable building assessment systems (Fowler and Rauch, 2006; Gibberd, 2005), green building rating systems (Gowri,2004), building performance assessment methodologies (Sinou and Kyvelou,2006),and green building assessment tools (Ali and Nsairat,2009) are some of the common terms used by the researchers to explain rating systems which developed to measure or evaluate performance of projects under sustainable development. Although each gives similar meaning, this research is focused buildings rather than environment and also rating systems rather than assessment, therefore, the term 'green building rating system' (GBRS) is referred in this paper. The purpose of this paper is to compare and contrast the green building rating systems achieving the following objectives.

- Identify green building rating systems and key environmental parameters
- Compare the rating systems reflecting values and priorities of key environmental parameters
- Discuss importance of water as a sustainable material
- Analyse key requirements and credits awarded for water efficiency and conservation in green rating systems
- Discuss credential given for water handling and monitoring during construction phase in GBRS

2. BACKGROUND TO THE RESEARCH

2.1. INTRODUCTION TO GREEN CONCEPT AND GREEN RATING SYSTEMS

Green building concept has become a flagship of sustainable development in this century that takes the responsibility for balancing long-term economic, environmental and social health (Ando *et al.,* 2005 cited in Ali and al Nsairat, 2009). Numerous benefits of green buildings were identified by many researchers. For example green buildings are energy efficient, water conserving, durable and non-toxic and high recycled content materials (Ali and al Nsairat, 2009); increases occupant productivity, enhances marketability , reduce operating cost (Fowler and Rauch, 2006); longer lifespan, reduced replacement and operation cost (Davis Langdon, 2007). Moreover, Sev (2009a) stated green building optimises efficiencies in resource management and operational performance; and minimises risks, which threaten the human health and environment'.

As stated by Fowler and Rauch (2006), there is hundreds of building evaluation tools that focus on different areas of sustainable development and are designed for different types of projects world-wide. These tools include life cycle assessment, life cycle costing, energy systems design, performance evaluation, productivity analysis, indoor environmental quality assessments, operations and maintenance optimization, whole building design and operations tools, and more. Ali and Nsairat Al (2009) divided these assessment tools into two groups. First group includes criteria based system such as BREEAM (Building Research Establishment's Environmental Assessment Method), LEED (Leadership in Environmental and Energy Design), GBTool, Green Star. The second group includes life cycle assessment (LCA) methodology. As Ali and Nsairat Al (2009) stated, since late 1990s methods for environmental assessment of building based on LCA have been developed for the building sector and also as stated by Cole *et al.,* (n.d), the field of building environmental assessment has matured remarkably quickly since the introduction of BREEAM in 1990. The BREEAM is the world's longest established environmental assessment method for the UK building industry as the benchmark for assessing the environmental performance. The primary aim is to mitigate the life cycle impacts of new buildings on the environment in a robust and cost effective manner (BREEAM, 2011). In the meantime, LEED is the most popular and widely used green building assessment tool for buildings. It was first introduced in 1998 in the US (USGBC, 2013). As Gowri (2004) mentioned, later many rating systems were developed based on the original international rating systems such as LEED and BREEAM, or integrating few other rating systems. BREEAM Canada, BREEAM Greenleaf, LEED India are examples of such efforts. As stated by Boonstra and Pettersen (2003), the latest tools address environmental issues not only during particular design stages but also in building operation. It is true, because the main objective of many green assessment systems is promote and integrate whole building design while reducing environmental impact and recognising the environmental leadership. Simply, each rating system designed to reflect the different phases in the building life cycle. Moreover, Green Star South Africa identified green rating system as a common language and standard method of measurement for green buildings (GBCSA, 2010).

2.2. IMPORTANCE OF WATER IN SUSTAINABLE DEVELOPMENT

As described by Sev (2009b), the relationship between sustainable development and the construction industry has become clear, since construction is of high economic significance and has strong environmental and social impacts. Moreover, Sev (2009b) mentioned while traditional design and construction activities focus on cost, performance and quality issues, sustainable design and construction adds the issues of minimization of resource consumption, environmental degradation and healthy and comfortable built environment. As stated by Dalton and John (2008), sustainability issues need to be addressed at the development level as a whole. The report of David Langdon (2007) explained that rapid change in priorities in the construction industry in Europe, North America, Asia and Australia with sustainability and the issues of global warming and resource conservation quickly are becoming high priority subjects. Furthermore, Fawcett *et al.* (2012) mentioned an objective of sustainability is to avoid or minimise any damaging future consequences from current consumption and investment activities. Therefore, many green building assessments discussed and identified protection and conservation of water as one of the fundamental principles concern for sustainable construction. As mentioned by Guggemos and Horvath (2006), construction industry is one of the largest users of water along with energy and material resources. Moreover, many studies (Economist, 2008; OECD, 2008) predicted that water is a scarce resource for many parts of the world and availability of potable water is inadequate and shrinking (ABB review, 2011) and volume of potable water use for construction activities are high (Green roads TM manual V1.5). McComack *et al.* (2007) mentioned that while an enormous amount of water is used to operate buildings, a considerable amount of water is also used for extraction, production, manufacturing, delivery of materials to site and the actual on-site construction process. The report of David Langdon (2007) explained that, a waterless future ultimately means cost increases; desalination, recycled water, third pipes, grey water, black water, water tanks etc. Thus, all these facts prove the importance of addressing water in sustainable development.

3. RESEARCH METHOD

The materials compiled in this document through literature review and information available in internet are taken directly from the rating system websites. Although, the search identified several rating systems, but due to inconsistency of evaluation criteria, and for want of authorization to download, some rating systems could not be considered for the analysis though they are well- known in the construction industry. For example Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) Japan; Green Globes-Canada; GBTool are some of them. Moreover, while selecting rating systems, screening criteria such as relevance, measurable, applicability and availability (Fowler and Rauch, 2006) were considered. The interpretations of the terms used are as follows. ‘Relevance- does the rating system provide a “whole building evaluation” or individual design feature?; ‘Measurable-‘does the rating system use measurable characteristics?’; Applicability- does the rating system designed for new construction and non-domestic?’ and Availability- Is the latest version of rating system easily available? After screening all the aspects, the sample consisted with the eleven green rating systems covering Asia, Europe, North America, Australia and South Africa as shown in Table 1. Furthermore, Table 1 gives reference for the document referred for the analysis, number of category (water, energy, site.) and certification level (Benchmarks) considered under each GBRS.

Table 1: Summary of Green Building Rating Systems

No.	Green Rating Systems	Country	Document considered	*Nr. of category	Certification Level
1	BREEAM	UK	NC 2011 SD5073	8	Pass, Good, Very good, Excellent
2	LEED	US	NC-2009	7	Certified, Silver, Gold ,Platinum
3	HK- BEAM	Hong Kong	2004 V4/04	6	Bronze, Silver, Gold ,Platinum
4	Green Star-AUS	Australia	2011 Office v3	9	Best Practice, Australian Excellence, World Leadership
5	BCA Green Mark	Singapore	NRB/V4.1/2013	5	Certified, Gold , Gold Plus, Platinum
6	GRIHA	India	2010 Volume 1	4**	1 Star, 2 Star, 3 Star, 4 Star, 5 Star
7	Green Star -SA	South Africa	2008 Office v1	9	Best Practice, South African Excellence, World Leadership
8	GBI	Malaysia	NC 2009 version 1	6	Certified, Silver, Gold ,Platinum
9	Green Star -NZ	New Zealand	Office 2009	9	Good Practice, Best Practice, NZ Practice, World Excellence
10	GreenSL	Sir Lanka	2010 Version 1	8	Certified, Silver, Gold ,Platinum
11	Pearl -BRS	Abu- Dhabi	2010 Version 1.0	7	1 Pearl, 2 Pearl, 3 Pearl, 4 Pearl, 5 Pearl

* Nr. of category counted including innovation category

** In GRIHA (Green Rating for Integrated Habitat Assessment) 34 criteria discussed under 4 main categories.

4. ANALYSIS OF KEY ENVIRONMENTAL PARAMETERS IN GREEN RATING SYSTEMS

Green rating systems cover number of environmental and social parameters that assess phases in a building life cycle. As stated by Gowri (2004), terminologies, structure of rating systems, relative importance of the environmental categories, and documentation requirements for certification are differed from one given to another rating system. This is because each country is launching indicators/parameters for its own market even though there are some similarities. In general, Site, Water, Energy, Materials and Indoor Environment are the five main environmental categories focus in GBRS addressing building design and life cycle performance (Gowri, 2004). Apart from that section like management, social & cultural awareness, pollution, transport could be seen within the rating systems. It is pertinent to note that in all the GBRS, there is a provision for 'Innovation Design' and allocated few credits for it. The BREEAM has given the maximum credit for Innovation. As mentioned by Gowri (2004), each category has number of prerequisites and all the projects must meet all the prerequisites to qualify for certification because prerequisites are critical since no credits points allocated towards the overall score but must be met irrespective of meeting other credit requirements.

After reviewing each system, it was identified many rating systems were given more credits for the 'Energy section' (Please Refer Figure 1). In BCA Green Mark Singapore, out of 190 credits, 116 credits assigned for energy category and in order to achieve green mark award, minimum 30 points required to fulfil from the energy section (BCA, 2013). In HK-BEAM (Hong Kong - Building Environmental Assessment Method), even allocated more credits for energy, in order to qualify for the overall grade it is necessary to obtain a minimum % of credits from Indoor Environmental Quality (IEQ) (HK-BEAM, 2004). This explains number of criteria used and structure may vary strongly between the systems. Figure 1 provides the overall picture of credits distribution among the key parameters and weightage (%) only shown for the main key environmental parameters in the order of Sustainable Sites, Water, Energy, IEQ and Materials. In addition, Green Star - Australia rating system allocated significant credits for Transport (C-11) and Emission (C-19) aspects. The BREEAM allocated for 9 credits for transport, 7 credits for waste and 13 credits for pollution aspects respectively. In addition, 10 credits allocated for the 'Innovation work' in the BREEAM. In Pearl-BRS assigned 43 points for the precious water including storm water which represents 23.9% from the total.

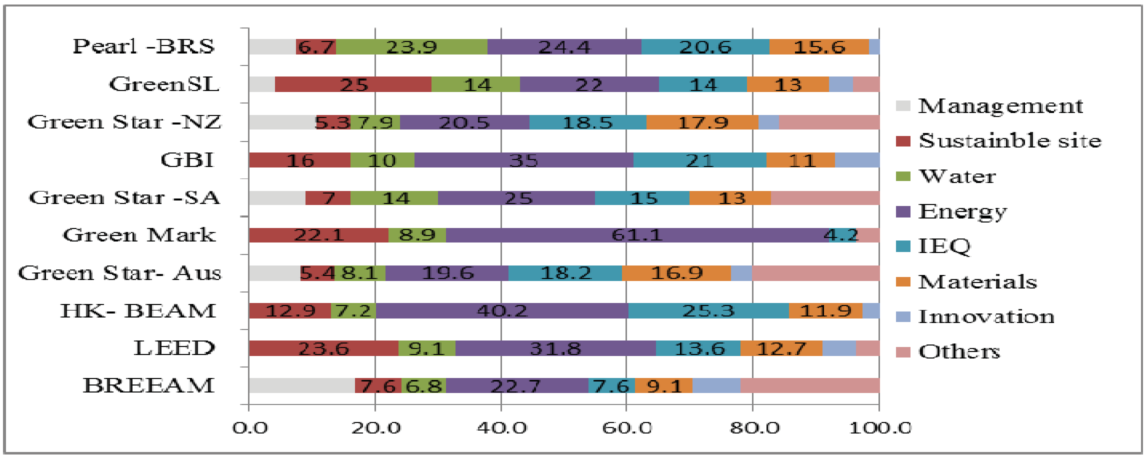

Figure 1: Analysis of Key Parameters Identified by Green Building Rating Systems

5. Key Requirements and Credits Awarded for 'Water' in Green Rating Systems

Table 2: Water Requirements Identified by Green Building Rating Systems

No	*Requirements*	*Description*
1	Reduce building water use	Reduce potable water consumption in the building through the use of water efficient components (using efficient fixtures like low-flow fixtures and appliances, etc.)
2	Water efficient plumbing fixtures and fittings	To reduce potable water & unregulated water consumption by encouraging specification of water efficient equipment
3	Water efficient landscaping / irrigation	Intent is to limit or eliminate the use of potable water for landscape irrigation and to minimize the load on the municipal water supply and depletion of groundwater resources
4	Water recycle and reuse including rainwater	Encourage rainwater harvesting and recycling of grey water in order to reduce freshwater consumption
5	Water monitoring, leak detection & prevention	Reduce wastage of freshwater through monitoring, reduce the impact of water leak and allow for auditing of water use
6	Water Quality	Intent is to ensure that quality of potable water delivered to building users is satisfactory and meet the water quality norms as prescribed in the standards for various applications
7	Innovative waste water technologies	To reduce wastewater generation and potable water demand while increasing the local aquifer recharge
8	Innovative water transmission	To limit the use of non-renewable energy for water transmission
9	Efficient discharge to foul sewers	Reduce volumes of sewage discharge from buildings
10	Water efficiency in air conditioning (Heat rejection water)	To limit or eliminate the use of potable water for air conditioning make-up while using of condense water for irrigation
11	Water Consumption for fire systems	To limit or eliminate the use of potable water for fire systems by promoting the use of recycled water and/or alternatives
12	Efficient water use during construction	Minimize the use of potable water during construction

As discussed in previous sections 'Water' is one of the key environmental parameters identified in green building rating systems. The purpose of this section is to analyse, how and what extent green rating systems address the water element in order to sustain water resources for the future generation. It was identified that intent of each green rating system is to reduce or eliminate the use of potable water for many purposes during the project lifecycle. Some GBRS included prerequisites for water section, LEED and Pearl BRS are examples for such. All the requirements (sub- sections) identified under water section in each rating system summarised into twelve headings as shown in Table 2. In addition, Table 2 provides the brief description to explain the commitment expect from each requirement. It is important to note, the storm water management did not consider for the analysis. From the sample, Pearl BRS Abu-Dhabi is the only rating system addressed storm water management under the water section. All other GBRS addressed storm water management under the sustainable site or management sections. Table 3 provides the matrix which shows credits distribution against the water requirements addressed by each GBRS.

Table 3: Matrix for Credits Distribution against Water Requirements and GBRS

	Water requirements and credits distributions in GBRS	**BREEAM-UK**	**LEED -US**	**BEAM - Hong Kong**	**Green Star- Australia**	**Green Mark- Singapore**	**GRIHA - India**	**Green Star- South Africa**	**GBI- Malaysia**	**Green Star- New Zealand**	**GreenSL - Sri Lanka**	**Pearl BRS-Abu Dhabi**
1	Reduce building water use	5		3	5		2	5		7	4	19
2	Water efficient plumbing fixtures and fittings	1	4	2		10			2			
3	Water efficient landscaping /irrigation		4	1	1	3	3	3	2	1	4	8
4	Water recycle and reuse including rainwater			3			5		4			
5	Water monitoring, leak detection & prevention	3		2	1	2		2	2	2		4
6	Water Quality			2			2					
7	Innovative waste water technologies		2				2				4	
8	Innovative water transmission										1	
9	Efficient discharge to foul sewers			1								
10	Water efficiency in air conditioning				4	2		4		2	1	8
11	Water Consumption for fire systems				1			1				
12	Efficient water use during construction						1					
	Total Points allocated for water section	**9**	**10**	**14**	**12**	**17**	**15**	**15**	**10**	**12**	**14**	**39**
	Total Points including innovation and bonus	**132**	**110**	**194**	**148**	**190**	**104**	**107**	**100**	**151**	**100**	**180**
	(%) from total	**6.8**	**9.1**	**7.2**	**8.1**	**8.9**	**14.4**	**14.0**	**10.0**	**7.9**	**14.0**	**21.7**

According to Table 3, many GBRS allocated range of 10-15 credits for the water section. The maximum points allocated in the Pearl BRS Abu-Dhabi rating system which is 39 points out of 180 (21.7%). Although, altogether twelve requirements identified about the water category, it is apparent that few requirements/strategies only addressed in each rating system. As shown in Table 3, GRIHA (Green Rating for Integrated Habitat Assessment) India and BEAM-Hong Kong are the only rating systems addressed more than six requirements relevant to water efficiency and conservation. However, it was observed that many such requirements are covered through different headings in other systems. For example in Green SL even there is no separate requirement for water recycling and rainwater harvesting, it is addressed under the requirement of innovative waste water technologies. In addition, recording and monitoring potable water consumption during construction, water pollution during the construction and water quality are addressed under Management, Sustainable Sites, and Health & Well-being categories in BREEAM, HK-BEAM and Green Star – Australia rating systems. Moreover, Figure 2 clearly illustrated the weightage (%) given for water category. Out of eleven GBRS, Pearl Abu-Dhabi, GRIHA- India, GreenSL, Green Star- SA and GBI- Malaysia came to the top five ranks. Less weightage was given in the BREEAM which was 6.8%. Although, Australia is considered as a water crisis country, comparatively less priority has been given for water section.

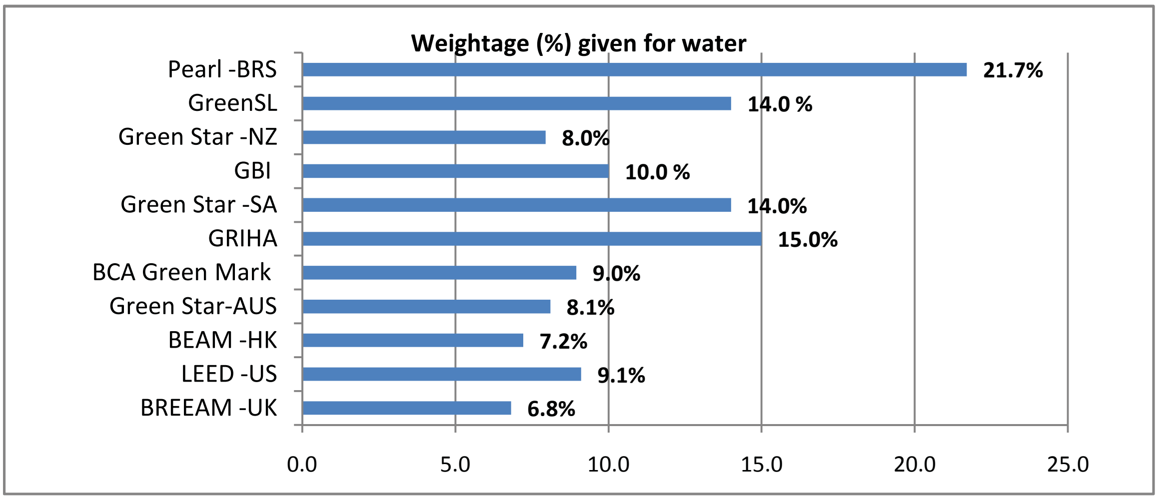

Figure 2: Weightage Given for Water Category by GBRS

Table 4: Highest Category and Priority given for Water

Rating System	Prority Level given for water	Highest Priority category
BREEAM -UK	8out of 10	Energy
LEED -US	5 out of 7	Energy
HK- BEAM	5 out of 6	Energy
Green Star-AUS	5 out of 9	Energy
Green Mark	3 out of 5	Energy
GRIHA -India		Energy
GBI -Malaysia	5 out of 6	Energy
Green Star -NZ	6 out of 9	Energy
GreenSL	3 out of 8	Sustainable Site
Pearl -BRS	2 out of 7	Energy

Table 4 summarises the highest category and priority level given for the ‘water category’ by each green rating assessment system. Except GreenSL rating systems, ‘energy category’ received the highest ranked according to the credits allocation. It shows the priority level given for water differs from rating system to system. Pearl- BRS was given the second place while Green Mark and GreenSL giving the third place for the water section. BREEAM has given the least priority level compared to other GBRS. As stated by Gowri (2004), though energy efficiency is a major component of designing a green building, several other basic sustainability requirements need to be met before claiming the additional credits for energy efficiency. At present water is identified as a global issue and therefore water shallalso to be received a greater priority.

6. Credential Given for Water During the Construction Phase in Green Ratings

Water is one of the most important natural resources for the development of all economic activities, taking place to care for the environment and quality of life in the society. Therefore, availability and management of water resources is essential for a long term sustainability of any country. After reviewing the green rating assessment systems it was identified that intention of all the rating systems is to reduce the potable water consumption. Moreover, each rating system identified the strategies/requirements for the efficiency use of potable water throughout the building lifecycle as discussed in Section 5.0. It was identified that the requirements, points or credits distribution and priority order are unique to a specific country. Moreover, during the analysis it was found that except few, many GBRS have not addressed the use of potable water in an efficient manner during the construction stage although rating systems designed to measure whole-life performance of a building project. Among the sample; LEED, HK-BEAM, Green Mark, Green Star, GBI, GreenSL and Pearl BRS are belong to the above category. BREEAM-UK and GRIHA- India are two rating systems which addressed and allocated credits for the monitoring and handling potable water consumptions during the construction phase, from the sample selected. In the BREEAM, one credit was allocated for recording and monitoring potable water consumption during the construction under 'Management' section. GRIHA – India is the only rating system specifically addressed separate criteria for the water conservation during the construction phase. Basically, purpose is to minimize the use of potable water during construction and encourage alternative methods which consume less water. For example, use materials such as pre-mixed concrete for preventing loss during mixing or use recycled treated water and control the waste of curing water (EARI, 2010). Importantly, one credit has been allocated for the water pollution during the construction in HK-BEAM rating system. As mentioned earlier, water is a changeable resource for Abu-Dhabi (ADUPC, 2010), Therefore, Pearl BRS has given more weightage to 'precious water'. However, controlling potable water during the construction was not acknowledged in Pearl rating system though large amount of mega scale building and civil construction projects involve and even though, water supply completely depends on desalinated water for construction work.

As stated by Waidyasekara *et al.,* (2012) lack of understanding of how water is used and how water is wasted are major challenges faced by the industry and there is no best practices evolved about water used for the construction sites and it is rarely addressed. There is therefore, it is important to address water handling and monitoring during the construction phase and cannot be ignored because water is an inevitable natural resource used in the construction industry. As stated by Utraja (2010), quality and quantity of water also has greater effect on the strength of mortar and concrete used for construction work. Although, Ali and Nsairat Al (2009) defined rating system as a management tool that organize and structure environmental concerns during the design, construction and operation phases, still many ratings systems need to be improved and extended to the construction phase. In terms of water efficiency and conservation, existing rating systems fairly address benchmarks and performance indicators for the building operation phase. However, none of them address any benchmarks for activities during the construction phase. This supports the statement mentioned in the BREEAM technical manual (2011), 'at present data from construction sites do not generally exist in enough detail to set benchmarks and targets, BREEAM therefore does not set any requirements in terms of specific targets for reducing energy, water and transport consumption resulting from the construction process.' The similar pattern could be observed from other rating systems as well. However, Waidyasekara et al., (2012) emphasised the importance of addressing water pollution and damage to the environment due to construction activities and necessity of implement rules and regulations towards water monitoring and handling in construction sites. Since many researchers have already identified the entire world is facing water crisis in very near future, individual green rating systems have a big role with sustaining potable water for the future generation addressing not only during the operation phase but also during the construction phase as well.

7. CONCLUSIONS

Construction industry is more responsible and has huge impact on creating a sustainable built environment. At present, construction industry is attracted and attached with labels of environmental tools which are designed to promote and integrate whole building design while reducing environmental impacts. Simply the rating systems act as a standard method of measurement for green buildings. It is noted, protection and conservation of water is one of the fundamental principles concerned in the sustainable development because at present water is a scarce resource and considered as a global issue.

This paper attempted to simplify how and in what strategies water efficiency and conservation is addressed in the existing green building rating systems. From the comparison of the eleven GBRS, it was found out there exist the different importance level, structure, and credits allocation between each system. Except GreenSL, all other rating systems were given the highest rank to 'Energy' because still energy is a global issue. Based upon the detailed analysis, the paper draws the following conclusions with respect to the water section addressed in the rating systems. It was found that in terms of water, intention of each rating system is to reduce potable water consumption compared to the benchmark buildings and addressed many directions to conserve and monitor water throughout the project life cycle. According to the rating system, requirements or strategies, credits allocation, and the project phase have been addressed in different manner. Water category was given the highest weightage by Pearl BRS-Abu Dhabi (21.7%) and the least weightage given in the BREEAM which is 6.8%. Requirements addressed by all GBRS grouped into twelve factors. Most of the GBRS have addressed few requirements /strategies stated in Table 3. It is pertinent to note that all the rating systems have well addressed water conservation methods during the in-use phase. However, credential given for the construction phase is directly addressed by only few rating systems like GRIHA and BREEAM. In general, all systems allocates more credits for limit or eliminate the use of potable water for landscaping and irrigation purposes, water recycling and water efficacy in HVAC. It further, each rating system encourages rainwater harvesting, and use of grey water, and condense water as an alternative source to reduce potable water consumption.

Finally, based on the findings, the paper suggests green building rating systems need to be reviewed and revised in terms of water efficiency and conservation with reference to the construction phase through establishing new benchmarks.

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CONTRIBUTION OF BUILDING MANAGEMENT SYSTEM TOWARDS SUSTAINABLE BUILT ENVIRONMENT

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ABSTRACT

The biggest challenge faced by the community is controlling and monitoring the performance of built environment facilities in a sustainable way. From this dimension, effective use of Building Management System (BMS) in the built environment is representing a significant strategy in relation to economic, environment and social perspectives. Higher energy efficiency, lower operating and maintenance costs, better indoor air quality, greater occupant comfort and productivity are the major achievements of a successful BMS. Therefore, at present it is so evident that, many organizations are enhtuastic to allocatea substantial investment, inorder to, install, commissioning, operation and maintenance of BMS. However, to obtain the optimum use of BMS is still challenging among the building users. Thus, the requirement of developing a framework for functionality of BMS is essential in order to gain maximum benefits through operating building automation and control systems.

The aim of the paper is to investigate the contribution of BMS in achieving a sustainable built environment. The findings are achieved through conducting literature and documentary review available in the built environment andanalyzing green building rating systems to find out the input of BMS towards sustainable built envionemnt. Therfore, comparative study conducted between LEED, BREEAM and GreenSLrating systems.Based on the findings, theoretical framework was developed to facilitate contribution of BMS in sustainable development. Moreover, the paper is engaged in analysisngthe credit contribution of BMS in order to gain the green rating certification.

***Keywords**: Building Management System; Green Building Assessment Tools: Sustainable Built Environment.*

1. INTRODUCTION

The biggest challenge, faced by the community is controlling and monitoring the performance of built environment facilities in a sustainable way. As explained by Forsberg and Malmborg (2004), built environment plays a vital role in the society of today, being a result of a number of social and economic processes that are central to the sustainable development. From the recent years, the pursuit of sustainability has become a mainstream of building design objectives as the physical environment of the earth is deteriorating (Wong and Fan, 2012). Therefore, sustainable development is now become the fundamental approach of creating the competition over built environment and more and more methods, put into practices to achieve sustainable built environment. Building Management System (BMS) is one of the new and innovative technologies, which has emerged in recent years and makes potential achievement of more sustainable designs. KMC Controls (2011) justified that the building sustainability could be achieved through higher energy efficiency, lower operating and maintenance costs, better indoor air quality, greater occupant comfort and productivity through implementing BMS.

In addition, Sinou and Kyvelou (2006) stated that the growth and the use of building performance assessment methodologies are further known as the green building rating systems, for an example LEED (Leadership in Energy and Environment Design) in the United States, BREEAM (Building Research Establishment Environmental Assessment Method) in United Kingdom, CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) in Japan, Green Starin Australia contribute greatly for the integration of methods and practices favouring sustainability in the

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building sector. Consequently these building performance assessment methodologies act as the pathway of achieving sustainability in the built environment.

According to KMC Controls (2011), sustainability may be driven by a number of factors such as environmental stewardship, the desire for green building certification, or the financial promises of lower operating costs. Hodges (2005) stated that implementing sustainability and green building approaches, organizations will be benefited through greater financial returns, increased standing in the community, improved productivity and reduced detrimental effects on the environment.Moreover, Waidyasekara and Sandamali (2012) mentioned that green buildings provide many benefits to the organisation, for its employees and to the whole society over to its initial cost.Therefore, selection of the appropriate sustainable approach is represented with a crusialstrategy in the design and construction of a building. Croome, *et al.,* (2004) recognised the rational use of natural resources and appropriate management of the building stock will contribute for saving scarce resources, reducing energy consumption, and for improving environmental quality. As revealed from literature, building management systems or automation systems is empowered to play a vital role in controlling and monitoring the functions of building in a sustainable way (Brown, 1990; KMC Controls, 2011). However, the input of BMS in sustainable rating systems and its contribution towards sustainability were given the least priority in the available literature.

Therefore, the aim of the paper is to investigate the contribution of BMS in achieving sustainable built environment. The following objectives were set in order to achieve the above aim.

- Identifying features and functions of BMS and its contribution to sustainability
- Developing a theoretical framework for the contribution of BMS under the philosophy of sustainable built environment
- Identifyingthe inputs of the BMS in green rating systems towards green certification

2. LITERATURE REVIEW

2.1. SUSTAINABILITY IN BUILT ENVIRONMENT

Sustainability, as a concept is emerged with the establishment of the World Commission on Environment and Development (WCED) by the United Nations in 1983. According to Carew and Mitchell (2008), the sustainability literature supports the subdivisions of the broader concept into the secondary interrelated concepts like environmental, social and economic sustainability. The Brundtland Commission (1987 as cited in Fellows, 2006) defined sustainable development as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This is the common and most popular definition used to describe sustainable development. As stated by Shah (2007), over 500 definitions of sustainability and sustainable development were spawned by various governments, professional bodies, institutions and organizations.

Akadiri and Olomolaiye (2012) pointed out that, the building industry is a vital element of any economy which has a significant impact towards the environment. With respect to such significant influence of the building industry, the sustainable building approach has a high potential to make a valuable contribution to sustainable development. Croome**,** *et al.,* (2004) identified five objectives for sustainable buildings such that resource efficiency, energy efficiency (including greenhouse gas emissions reduction), pollution prevention (including indoor air quality and noise abatement), harmonisation with the environment, and integrated and systemic approach. Three dimensions of sustainability; environmental, economic and social were interpreted for a sustainable building by Kohler (1999) as shown in Figure 1. According to Kohler (1999), Ecological Sustainability can be quantitatively analysed with respect to the energy and mass flows in time and space within a life cycle assessment in terms of resource and ecosystem. In addition to that, Economic sustainability can be divided into two as investment and use costs. Hence, instead of minimizing investmentcost through crossing low-cost of building processes and products, it is preferable for a given investment to find solutions that have the highest durability and reusability. Hence, it will pave the way towards, the social and cultural aspects of sustainability including comfort and health protection, and preservation of values, which is one of the main motivations behind any conservation projects (Kohler, 1999).

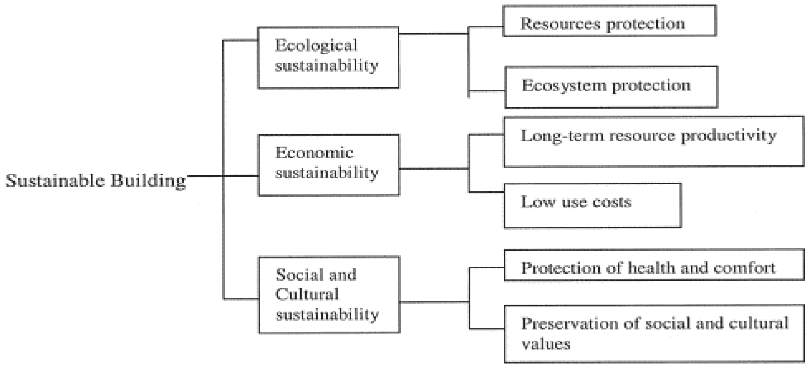

Figure 1: Three Dimensions of Sustainable Building, (Source: Kohler, 1999)

2.2. INTRODUCTION TO BUILDING MANAGEMENT SYSTEM (BMS)

Brown (1990) defined BMS as "a system designed and implemented to control and monitor the functions of a building and its associated plant". As depicted in literature, the term Building Automation System (BAS) and Building Control System (BCS) similar terms which are utilised to refer the BMS. As explained by Brown (1990), all subsystems of BMS work together in a single building. Moreover, BMS is shared with the same building information affecting each other. Therefore, it should be an integrated within the same information platform. In order to achieve specific goals, several integrated BMS solutions have been worked out, however, these solutions may differ according to the requirements as explained by Brown (1990). Jiang *et al.,* (2011) elaborated the general structure of BMS as illustrated in Figure 2. According to Figure 2, BMS uses computer based monitoring to coordinate, to organise and to optimise building control sub systems such as security, fire/life safety, elevators, and others. Howevr, it is aoded in controling connected plant to maintain a preset requirementof the building. BMS is also connected in monitoring inputs such as temperature readings and process them using digital controllers to give control outputs back to the building. All the subsystems of the building are interconnected and information is passed across them using the network.

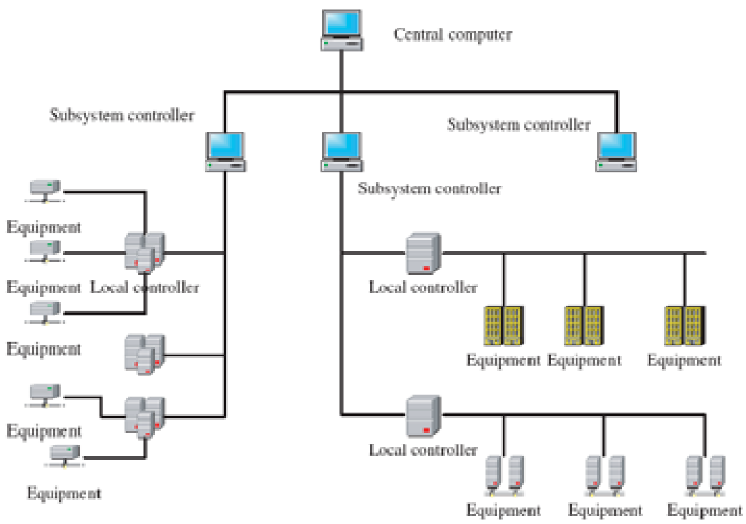

Figure 2: BAS System (Source: Jiang, *et al.,* 2011)

Allen and Remke (2008) stated that, the building automation or management system is used to control functions of a Heating, Ventilating and Air-Conditioning (HVAC) system including temperature and ventilation, as well as equipment scheduling. Apart from that, monitoring of utility demand, energy use, building conditions, climatic data, and equipment status are identified as the additional features which are includedinthe system.In addition, BAS is integrated with the additional building features such as video surveillance, access control, lighting control, and interfacing with the fire and security systems. Moreover, as mentioned by Allen and Remke (2008), utility load profiles, the trends and operation logs of equipment, and the generation of maintenance schedules are some outputs of BMS. The University of Bristol (2004) summarised the common capabilities of BMS include the followings.

- Equipment scheduling (turning equipment off and on as required)
- Optimum start/stop (turning heating and cooling equipment on in advance to ensure the building is at the required temperature during occupancy)
- Operator adjustment (accessing operator set-points that tune system to changing conditions)
- Monitoring (logging of temperature, energy use, equipment start times, operator logon)
- Alarm reporting (notifying the operator of failed equipment, out of limit temperature/pressure conditions or need for maintenance)

As stated by Anon (2005), incorporating the above capabilities a building can:

- Make the operation and management easy in complex mechanical and electrical services environments
- Monitor and control sophisticated equipment
- Ensure that building users are satisfied with the services provide all the time in a high service level expectancy environment.
- Enhance the lifetime of the plants and machinery
- Optimize energy consumption and save energy
- Disaster management and safety
- Meet regulations

Even though BMS is included with many features, as mentioned inCIBSE Guide H (1999), when deciding on the appropriate type of control system to specify for a building, it is essential to consider the benefits of a modern control system that are matched with the requirement of different groups of users involved with the building. Moreover, in order to gain the expected benefits, the system should be properly specified, installed, commissioned, operated and maintained. Table 1 listed some of the benefits to be achieved with an effective modern BMS according to the type of building stakeholder. In addition, Wang and Xie (2002) explained that the Facility Managers need BMS to control building performance, manage and distribute services, adapt rapidly changed the requirements and to provide important management information. Moreover, Wang (2010) highlighted main typical benefits of having BAS as; increased reliability of plant and services, reduced operating costs, building management, enhancing staff productivity, and protection of people and equipment.

The report CIBSE Guide F (2004) highlighted, BMS is empowered to improve the overall management and performance of buildings, promoting a holistic approach to controls and providing operational feedback. Furthermore, the same report cited 10% to 20% energy savings can be achieved by installing a BMS compared to independent controllers for each system.

Table 1: Benefits of BMS (Source: CIBSE Guide H, 1999)

Building Stakeholder	Benefits
Building owner	Higher rental value Flexibility on change of building use Individual tenant billing for services
Building tenant	Reduced energy consumption Effective monitoring and targeting of energy consumption Good control of internal comfort conditions Increased staff productivity Improved plant reliability and life
Occupants	Better comfort and lighting Possibility of individual room control Effective response to HVAC related complaints
Facilities manager	Control from central supervisor Remote monitoring possible Rapid alarm indication and fault diagnosis Computerised maintenance scheduling Good plant schematics and documentation
Controls contractor	Bus systems simplify installation Supervisor aids setting up and commissioning Interoperability enlarges supplier choice

2.3. CONTRIBUTION OF BMS IN SUSTAINABLE ENVIRONMENT

The concept of sustainability is regarded to be three-folds; environmental, social and economic, out of which environmental sustainability is considered to be the backbone of the other two. Morelli (2011) defined environmental sustainability as the meeting the resources and services needs of current and future generations without compromising the health of the ecosystems and this allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by human actions diminishing biological diversity. Gadakari, *et al.* (2012) explained economic sustainability is the term used to identify various strategies that make it possible to utilise available resources to best advantage and encourages its responsible use. Moreover, economic parametermake sure that the business is making a profit while addressing environmental concerns and contributing to the financial welfare of the owners, employees, and the community where the business is located. Social sustainability is the idea that "future generations should have the same or greater access to social resources as the current generation (inter-generational equity), while there should also be equal access to social resources within the current generation (intra-generational equity)".

As stated in the previous section, functions of BMS such as stop and start equipment when needed; monitoring space conditions and occupancies; and implementing sophisticated strategies will reduce overall energy use. Furthermore, BMS is contributed to improve indoor air quality through continual ventilation adjustments and air-quality monitoring; and maximise day lighting by automating shading systems (Gadakari, et al, 2012). Wu and Noy (2010) mentioned that a building knows when and where it is occupied able to limit its own energy use by confining the operation of power-hungry HVAC and lighting systems to the hours and areas of the building which are needed. Occupancy sensors are used to enhance the presence detection and accurate localised occupancy information to provide solutions that are energy-efficient without compromising on occupant comfort and productivity (Dounis et al., 2011 and Pandharipande and Caicedo, 2011). Johnson Controls, a leading producer of energy-saving equipment, explained that the companies could reduce energy bills by 20% to 25% by using efficiently programmed and monitored BMS and through other intelligent controls (Mazza, 2008). Ferguson, Director of Johnson Controls, said that the biggest savings arise through the management of heating and cooling. One degree Centigrade down in heating temperature will provide around 7% savings on the energy necessary to heat the building (Clarke, 2008). Katz and Skopek (2009) recognise not only the benefits of the BMS as decrease in building maintenance and energy costs; increase in productivity, rental incomes but also the guard against repair costs, productivity loss, revenue loss, and loss of customers to competitors. As stated by Gadakari, *et al*, (2012), social implication of intelligent technologies on our lifestyles needs to possese a delicate attention to ensure an enriching environment to make life meaningful amidst all the technological progress. Moreover, KMC Controls (2009) mentioned, a control system is fruitful for both individual comfort control as well as for an efficient use of equipment and power. And also historical data can be used either to improve building performance while maintaining occupant productivity.

3. Research Method

Literature available in the built environment and the documentary review were used to achieve the research objectives. Theoritcal framework for BMS towards sustainable built environment was developed based on the keyliterature findings. International green rating systems, Building Research Establishment Envionmental Assessment Method (BREEAM) as the world longest established rating system andLeasership in Energy and Envionmetal Design (LEED) as the most popular and widely used building assessment tool selected for the comparative analysis of BMS input towards green certification. In addition Local rating system Green^{SL} too considered during the analysis.

4. Proposed Theoretical Framework for BMS Towards Sustainable Built Environment

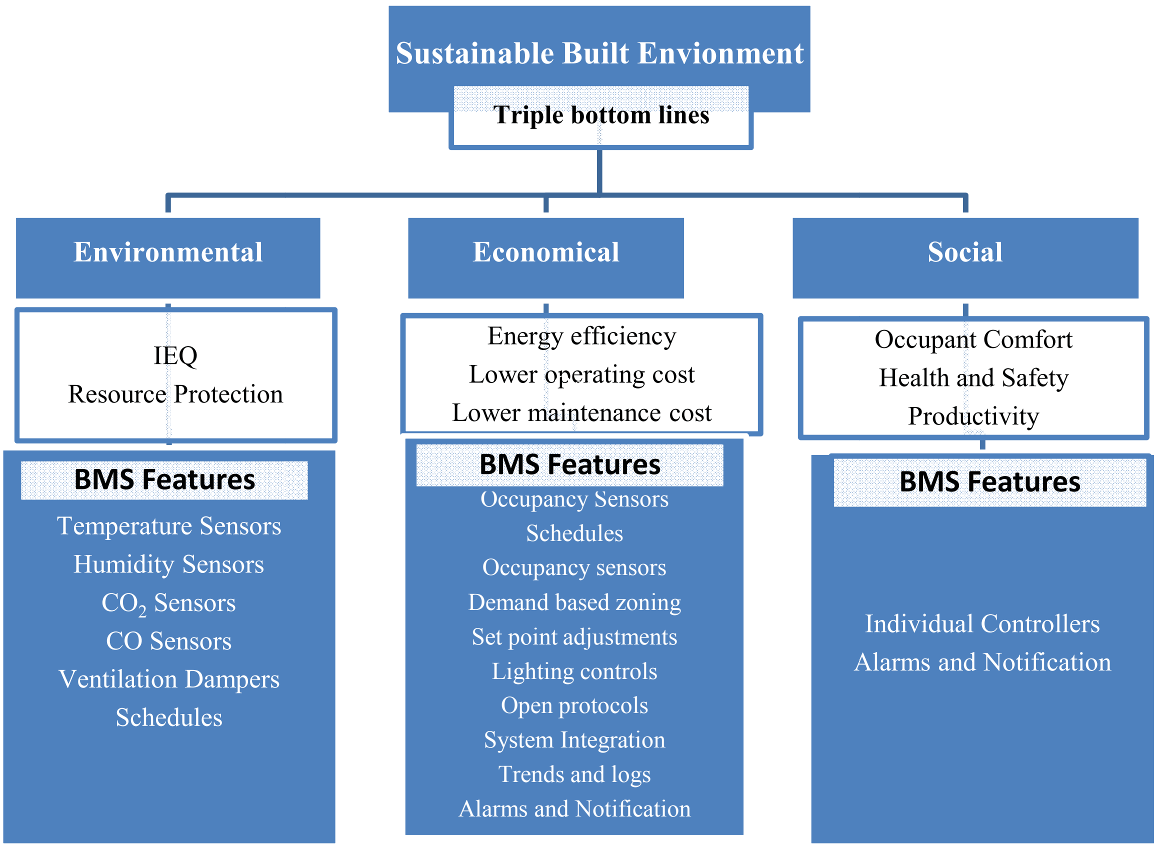

Figure 3: Proposed Theoretical Framework for BMS Contribution in Sustainable Built Environment

Sections 2.2 and 2.3 have discussed about the functions, features of BMS and its contribution in a sustainable built environment. Based on the key literature findings, theoretical framework was developed as illustrated in Figure 3. It is being facilitatedin identifying the contribution of BMS and justified characteristics that should be achieved in order of gaining sustainable built environment through BMS features. Since this research is at the initial stage, an expert opinion survey will be carried out as the next step to check the validity of the framework developed.

5. BMS INPUTSINGREEN BUILDING RATING SYSTEMS

A green building rating system provides an effective framework for assessing building environmental performance and integrating sustainable development into building and construction processes (Cole, 2003 cited Ali and Nsairat, 2008). Cole and Kernan (1996) stated that assessment measurements based on building life cycle is empowered to produce significant long-term benefits for building owners and occupants as this system support for solving existing building problems, limiting environmental impacts, creating healthier and more productive places and reducing building operations cost. LEED in United States, BREEAM in United Kingdom, CASBEE in Japan, Green Mark in Singapore, GRIHA in India and Green Star in Australia are some of the well-known rating systems around the world (Wikipedia, 2013). Although many green rating systems are currently available LEED, BREEAM and Green^{SL} were selected for the comparative study.

5.1. LEED - LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN – UNITED STATES

LEED is a credit based building rating system developed by the United States Green Building Council (USGBC). According to USGBC (2009), "LEED is a voluntary rating program, goal is to evaluate environmental performance from the whole building perspective over the building's Lifecycle, providing a definitive standard for what constitutes a green building". According to USGBC (2009), LEED is is involved with the promotion of a whole-building approach to sustainability by recognising performance in Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Regional priority, and Innovation and Design Process areas. KMC Controls (2011) highlighted the fact that a properly designed and installed building control system is eligible in leading fulfilled credits worth up to 48 points in the LEED rating system.In LEED, building automation hasan impactin gaining credits gain from Energy and Atmosphere (E and A), Indoor Environmental Quality, Water Efficiency, and Sustainable Sites sections (KMC Controls, 2011).Energy and Atmosphere (E and A) is the most impact section out of them (Please Refer Table 2).

5.2. BREEAM-BUILDING RESEARCH ESTABLISHMENT ENVIRONMENTAL ASSESSMENT METHOD – UNITED KINGDOM

The Building Research Establishment (BRE) of UK introduced the Building Research Establishment Environmental Assessment Method (BREEAM) in 1990, which was the first environmental assessment tool to be used internationally (Cassidy, 2003). The primary aim of BREEAM 2011 New Construction is to mitigate the life cycle impacts of new buildings on the environment in a robust and cost effective manner. According to the BREEAM 2011 NC, assessed the performance of buildings under the ten main sections and allocated different points for each section. They are Management, Health and Wellbeing, Energy, Transport, Water, Materials, Waste, Land use and Ecology, Pollution, and Innovation. Currently in the UK, clients, planners, development agencies and developers are using BREEAM to specify the sustainability performance of their buildings in a way that is quick, comprehensive and visible in the marketplace (Gowri, 2004; Potbhare *et al.,* 2009). Table 2 summarised the relevant sections that the BMS could contribute against the green certification in the BREEAM.

5.3. GREENSL RATING SYSTEM

Green^{SL} rating system was developed in 2010 by the Green Building Council Sri Lanka (GBCSL) for a new and existing buildings based on LEED rating system. Mudalige (2012) stated, GREEN^{SL} rating system has been introduced for the first time in Sri Lanka for built environment taking up the challenge to create sustainable buildings for the future.

Table 2: BMS Contribution in Green Rating Systems

LEED NEW		**GREEN SL**		**BREEAM**	
Sustainable Sites		**Sustainable Sites**		**Pollution**	
Light Pollution Reduction	1	Light Pollution Reduction	1	Reduction of Night Time Light Pollution	1
Energy and tmosphere		**Energy and Atmosphere**		**Energy**	
Fundamental Commissioning of Building Energy Systems	Required	Fundamental Building Systems Commissioning	Required	Reduction of Carbon Dioxide Emissions	15
Minimum Energy Performance	Required	Minimum Energy Performance	Required	Sub-Metering of Substantial Energy Uses	1
Optimize Energy Performance	1 to 19	Optimize Energy Performance	1 to 10		
On-site Renewable Engy	1 to 7	Renewable Energy	1 to 8	Sub-Metering of High Energy Load and Tenancy Areas	1
Enhanced Commissioning	2	Additional Commissioning	1		
Enhanced Refrigerant mgt	2	Ozone Depletion	1	External Lighting	1
Measurement and Verification	3	Measurement and Verification	1	Lifts	2
Indoor Environmental Quality		**Indoor Environmental Quality**		**Health & Wellbeing**	
Minimum Indoor Air Quality Performance	Required	Minimum IAQ Performance	Required	Glare Control	1
Environmental Tobacco Smoke (ETS) Control	Required	Smoke (ETS) Control	Required	Internal & External Lighting	1
Outdoor Air Delivery Monitoring	1	Outdoor Air Delivery Monitoring	1	Lighting Zones & Controls	1
Increased Ventilation	1	Increased Ventilation	1	Potential for Natural Ventilation	1
Indoor Chemical and Pollutant Source Control	1	Indoor Chemical and Pollutant Source Control	1	Indoor Air Quality	1
Controllability of Systems—Lighting	1	Lighting Controls	1	Thermal comfort	1
Controllability of Systems-thermal comfort	1	Comfort Controls	1	Thermal Zoning	1
Thermal Comfort-design	1	Thermal comfort, design	1		
Thermal Comfort	1	Thermal Comfort,	1		
Water Efficiency		**Water Efficiency**		**Water**	
Water Use Reduction	2 to 4	Water Use Reduction	2 to 4	Water Consumption	2
				Water meter	1
				Major Leak detection	1
Total contributory points	**45**	**Total contributory points**	**33**	**Total contributory points**	**32**

The GREENSL Rating System for Built Environment is a set of performance standards for certifying Built Environments in the form of commercial or institutional buildings and high-rise residential buildings of all sizes, both public and private. The intent is to promote high performance, healthy, durable, affordable, and environmentally sound practices for new and existing buildings (GBCSL, 2011). GreenSL rating system for built environment is addressed to eight aspects. Such that Management (MN), Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), Indoor Environmental Quality (IEQ), Innovation and Design process (ID), and Social and Cultural awareness (SC).

Table 2 summarised the contribution of building automation and control system in green building rating systems. LEED and Green^{SL} possess a similar structure. Instead of Indoor environment quality and sustainable site used in LEED and Green^{SL}, Health & wellbeing and Land use & ecology terms used respectively in the BREEAM rating system, althoughprovide with thesimilar meaning. After reviewing each rating system it was found that, building automation has the most impact on the 'Energy' section. In addition, BMS impacts on the IEQ, water, sustainable sites and pollution sections as well. However its contribution in each section is very. As mentioned in KMC controls (2011), it is important to understand the difference between a contributory credit and a compliance credit. It is furthermore eloberated, with rare exception, the use of a particular product or type of product cannot, in and of itself, lead to credit compliance. For the most part,products, of whatever type, contribute to the fulfilment of particular credits.How the particular features of BMS contribute to the fulfilment of particular credits in rating systems is shown from Table 2. It was found that BMS is contributed with the maximum points of 45, 33 and 32 for the green certification in LEED, Green^{SL} and BREEAM respectively.Another vital fact is that in each rating system credit achievement is impossible without the contributory help of the control system.

6. CONCLUSIONS

BMS is one of the innovative technologies emerged in recent years to make potential achievement of the sustainable designs.This research was carried out to determine how BMS features contribute towards a sustainable built environment. The paper is presented a theorical framework that developed for BMS based on the key findings of literature review and the documentary review. Furthermore, it was found that in order to get the maximum benefits from BMS,the system should be properly specified, installed, commissioned, operated and maintained in an addition match with the type and requirements of users involved in the building. Moreover, the paper is analysed itself on LEED, Green^{SL} and BREEAM rating systems to review the input of BMS in green certification. It was revealed thatthe building management system has the most impact on the Energy section. IEQ, water, and sustainable siteare other sectionsthat BMS is eligible to contributefuthrermore.The next step of the research is to develop an assessment framework to evaluate the contribution of BMS in acheiving the sustianble built environment.

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COOL PAVEMENT SYSTEMS AS A MITIGATION STRATEGY OF URBAN HEAT ISLAND EFFECT: A LITERATURE REVIEW

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ABSTRACT

The urban heat island effect is the rise of ambient temperature in urban areas due to the progressive replacement of natural surfaces. Buildings and paved surfaces are contributing most to this phenomenon as per the properties of their material. Conversely, urban heat islands have a direct influence on building occupants' comfort levels, building cooling loads and energy costs as well. Although there are existing researches on green buildings, there is a significant lack of literature on cooler paved surfaces; particularly in tropical countries.

To bridge this research gap, and to explore the applicability of cooler pavement systems in search of mitigating urban heat island effect in the micro and meso level, this study was executed as a desk study based on a literature survey of environmental implications of unsustainable rapid urban development, their mitigation strategies, and where existing pavement systems stood in all this. The literature synthesis of existing work by authors from around the globe led to the discussion and analysis of the paper, and resultant further study areas.

This paper compares alternative "cool" pavement systems, which are defined as pavements with improved solar reflectivity and permeability characteristics. The paper suggests how these can be used effectively in a sustainability conscious building facility, and by infrastructure developments which has a wider role of reducing local heat islands, increasing pedestrian comfort and reducing runoff water. The scope of this paper was limited to pedestrian pavements and gives reference to construction professionals who are engaged with sustainable building and infrastructure projects on their usability.

Keywords: *Green Building Materials; Pedestrian Pavements; Sustainability; Urban Heat Island Effect.*

1. INTRODUCTION

Since the end of the civil war in mid-2009, Sri Lanka's economy has been on a strong growth trajectory led by determined property and infrastructure development (Jones Lang LaSalle (JLL), 2011). However, such developments comes with a certain downside as identified by Sarat and Eusuf (2011) that with urbanization, buildings and paved surfaces have gradually replaced pre-existing natural landscape. As a result, solar energy is absorbed into paved materials, causing the surface temperature of urban areas to become 10-21^{0}C higher than the ambient air temperatures. This phenomenon is identified as the Urban Heat Island Effect (UHIE) and paved surfaces contribute considerably to this in cities because they cover a remarkably large fraction of urban surfaces (Levinson *et al.,* 2010; Pomerantz *et al.*, 2003). Hence, a pavement system of a building is directly linked with its environmental performance evidenced in the work of Lin *et al.* (as cited in Sarat and Eusuf, 2011) where it is reasoned that outdoor thermal environment is impacted by the built environment. The potential for research and development under sustainable construction and building materials into this area is still not fully harnessed in the Sri Lankan context although in the global context it is found that pavement construction materials have been historically used as a countermeasure for urban heat islands (Santamouris *et al.,* 2001). The aim of this research is to bridge this research gap exploring the environmental implications imposed by pedestrian pavement systems and how alternate cooler pavers can assist a city to achieve a level of sustainability. Methodology

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adopted for the research was gathering literature under the subject purview and synthesizing the existing work to identify prospective alternative pavement systems which have improved thermal and permeability characteristics over the existing systems. The study is limited to a desk study concerning sustainability in construction, urban heat islands and pedestrian pavement systems which are elaborated in latter parts of the paper arriving at a discussion of the topic and future study areas that needs to be undertaken.

2. METHOD: LITERATURE REVIEW

2.1. URBAN HEAT ISLANDS: A GLOBAL ISSUE

Grimmond *et al.* (2010) in their publication, "Climate and More Sustainable Cities: Climate Information for Improved Planning and Management of Cities" expresses that cities and their inhabitants are key drivers of global climatic change and they use a disproportionate share of resources and produces climate-altering atmospheric pollutants. Moreover, cities are the main source of anthropogenic carbon dioxide emissions due to the burning of fossil fuel for heating and cooling, industrial processing, transport of people and goods and so forth.

With more people being vulnerable to urbanization problems around the globe as urban population is ever increasing, which was estimated as 48% or three billion, is expected to be 6.3 billion by 2050 (Department of Economic and Social Affairs (DESA), 2012).The adverse effects of urbanization ranges from a global scale to regional levels, where it is more serious and obvious as industrial activities and heavy use of synthetic construction material are commonly observed (Rizwan *et al.*, 2008).

Furthermore, Rizwan *et al.* (2008) states that as a result, the natural environment and ecology are tremendously affected and have lost necessary balance. This has led to a phenomenon of higher ambient temperature, observed in cities as compared to its surroundings; called Urban Heat Islands (UHI).

This has been formally defined as the rise in temperature of any man-made area and is known to be caused by the progressive replacement of natural surfaces by built surfaces through urbanization (Pena, 2009;Wong *et al*., 2007).The urban heat island phenomenon is recognized to be a consequence of increased urbanization and abrupt changes in the outdoor environment. The temperature rises in urban environments are caused by the changes of street surface materials and reduction of green areas (Wong *et al*., 2007).

The causes of urban heat island effect are identified and listed by Santamouris (2001) as follows;

1. Absorption of short-wave radiation from the sun in low albedo (reflection) materials and trapping by multiple reflections between buildings and street surface
2. Air pollution in the urban atmosphere absorbs and re-emits long wave radiation to the urban environment
3. Obstruction of the sky by buildings results in a decreased long-wave radiative heat loss from street canyons. The heat is intercepted by the obstructing surfaces, and absorbed or radiated back to the urban tissue
4. Anthropogenic heat is released by combustion processes, such as traffic, space heating and industries
5. Increased heat storage by building materials with large thermal admittance. Furthermore, cities have a larger surface area compared to rural areas and therefore more heat can be stored
6. The evaporation from urban areas is decreased because of 'waterproofed surfaces' – less permeable materials, and less vegetation compared to rural areas. As a consequence, more energy is put into sensible heat and less into latent heat

7. The turbulent heat transport from within streets is decreased by a reduction of wind speed

Rizwan *et al*. (2008) cites several significant adverse effects of UHI;such as, the deterioration of living environment, increase in energy consumption (Konopacki and Akbari, 2002),an increase in mortality rates (Changnon *et al*., 1996), andan elevation in ground-level ozone (Rosenfeld *et al*., 1998). In their work Mirzaei and Haghighat (2010) further elaborates that UHI also intensifies pollutant concentration over urban areas. Furthermore, Taha (1997) explains how it impacts the local meteorology by altering local wind patterns, forming cloud and fog, increasing humidity, and changing the precipitation rate.

The field of UHI has become highly interesting for scientists and engineers due to its adverse environmental and economic impacts on the society (Rizwan *et al*., 2008). Different strategies have been developed by researchers to mitigate UHI and the most common strategies carried out by different municipalities are based mainly on the change of street pavement and roofs, commonly known as cool pavements and cool roofs (Kleerekopera *et al*., 2012). Several cities such as Houston have introduced cool pavement strategies in their plans to mitigate the UHI effect (Hitchcock, 2004).

According to He and Hoyano (2010) the reason for high contribution for UHIof buildings and infrastructure is that most types of pavement and building exteriors are fabricated from materials with low albedo and high thermal retention capacities, such as asphalt and concrete.

Conventional asphalt has an albedo of approximately 0.1; concrete has a higher average albedo of 0.45 (Asaeda *et al*., 1996). Moreover, Gui *et al*. (2007) points out thatasphalt covers as much as 29-45% of total urban surface area. Accordingly, Forkes (2010) in her study on Mitigating Urban Heat in Canada infers that cooler pavements help reduce UHIs.

2.2. NEED FOR PEDESTRIAN PAVEMENTS WITH PASSIVE FEATURES

Pedestrian pavements found in building and infrastructure developments are designed to be technically, economically and aesthetically suitable for users and developers (Mendoza *et al*., 2012). As discussed earlier, the most common types of pedestrian pavements are concrete (considered consistent, durable and economic) and asphalt: chosen for their initial low cost, but they have a shorter service life than concrete and more susceptible to damage from weather and normally require more maintenance, increasing their economic cost over time (Federation of Canadian Municipalities and National Research Council, 2004).

However, Mendoza *et al*. (2012) identifies that these designs fails to apply comprehensive life cycle environmental data to identify suitable construction solutions and urban management strategies that contribute to minimizing their environmental impacts.

In their work on relationship between pavement systems and building energy usage, Yaghoobian and Kleissl (2012) noted that radiative, conductive and convective properties of construction materials and the urban form can be engineered or selected to achieve different urban climate objectives which are used in UHI mitigation measures such as increases in albedo and urban greeneries.

This effort to mitigate urban heat islands are further reflected by Cambridge Systematics (2005) in their report which avers that cool pavement strategies seek to control the temperature of the pavement by controlling one or more of the material properties, i.e. albedo, permeability, conductivity, emissivity, thickness and convective airflow; as a direct action to control the heat island effect (US Environmental Protection Agency (EPA), 2008).

Therefore, permeable pavements are used as a sustainable building material for alternative designs. Forkes (2010) defines permeable pavements as paving methods for roads, parking lots and walkways that allow the movement of water and air around the paving material. This may be interlocking brick, gravel or open grid concrete or plastic cells. The permeability of the pavement makes it possible for water to infiltrate thoroughly to the soil.

However, as Lin *et al*. (as cited in Citraningrum, 2012) argues this infiltration may increase soil moisture and making it become softer, making it only suitable for light duty and infrequent usage area such as parking area or pedestrian access. Accordingly Citraningrum (2012) lists three such permeable pavements that are commonly used on the field: permeable asphalt concrete pavement, pervious concrete pavement, and permeable interlocking concrete pavers. He suggests that these permeable pavements when wet; can lower air temperature through evaporative cooling. Similarly, EPA (2008) explains that moisture within the pavement structure evaporates as the surface heats, thus drawing heat out of pavement.

In his studies Citraningrum (2012) agrees with other researchers that permeable interlocking concrete pavers (more commonly known as interlocking concrete pavement blocks) has a higher air temperature reduction and building energy consumption reduction compared to other type of pavements.

As discussed earlier, through urbanization cities replace most of the bare ground and vegetation with impermeable surfaces such as buildings and pavements which reduce the cooling caused by evaporation of water. Pomerantz *et al*.(2003) points out these effects of urbanization are difficult to reverse; according to Forkes (2010) measures are implemented to add vegetation in cities, and progressive replacement with permeable surfaces.

In the meanwhile, researchers like Pomerantz and Akbari (1998), Li (2012) and Yaghoobian and Kleissl (2012) focus on the colour of existing impermeable surfaces which affects the temperatures within the city; believing that the most practical means of mitigating urban heat islands is to make city surfaces more reflective of the sunlight, both visible and invisible (mostly infrared). The quantitative measure of the total solar reflectivity is called “albedo” (Pomerantz *et al*., 2003).

Therefore, pavement systems with high albedo (i.e. solar reflectivity) are used more frequently to mitigate urban heat islands. As Marceau and VanGeem (2007) points out, the widely acclaimed US based green building rating system LEED serves up to 2 points for reducing the heat island effect. These points can be obtained for using paving material with a solar reflectance index (SRI) of at least 29 for a minimum of 50% of the site hardscape (including roads, sidewalks, courtyards, and parking lots). The Sri Lankan green rating system Green^{SL} has a similar interest in heat island mitigation by means of paving material (Green Building Council Sri Lanka (GBCSL), 2010).

Essentially, high albedo and high emissivity paving material can be defined as cool pavements that help lower surface temperatures and reduce the amount of heat absorbed into the pavement (Forkes, 2010). Even so, permeable and porous pavement is sometimes also referred to as a cool pavement due to its ability to remain cool through using evaporation. A number of cool pavement alternatives are currently available as products, and these are either light in colour to reflect solar energy or may also be porous to allow evaporation (EPA, 2008). Table 1 gives a comparison made between such pavement systems;

Table 1 Comparison of Existing Pavement Systems in Relation to their Cool Features

Technology	Initial solar reflectance	Solar reflectance over time	Permeability[4]	Service life (Years)	Impact on Urban Heat Islands
Conventional asphalt	5-10%[1]	10-15%	Low	20-30	Low
Rubberized asphalt	5-10%[2]	20-15%	Low	20-30	Low
Porous asphalt	5-10%[2]	10-15%	High	15-20	Medium
Conventional concrete	35-40%[1]	20-30%	Low	15-20	Medium
Pervious concrete	35-40%[2]	35-40%	High	15-25	Medium
White cement concrete	70-80%[1]	40-60%	Low	20-35	High
Concrete pavers	10-80%[2]	10-80%	High	15-20	Medium
Titanium Dioxide cement	35-40%[2]	35-40%	Low	20-35	High

Technology	Initial solar reflectance	Solar reflectance over time	Permeability[4]	Service life (Years)	Impact on Urban Heat Islands
Colour pigments and seals	10-80%[3]	10-80%	Low	3-7	Medium
Chip seals	20%[3]	Declines	Low	5-10	Medium
Scrub/ Slurry/ Cape seals	5-10%[2]	10-15%	Low	3-7	Low
White topping	40%[3]	25%	Low	10-15	Medium
Resin based products	33-55%[2]	Declines	Low	Unknown	Medium
Grasspave and Gravelpaveproducts	26-60%[2]	26-60%	High	10-15	Medium

[1] Levine (2011)
[2] Nichols Consulting Engineers (2012)
[3] EPA (2008)
[4] Citraningrum (2012)

As evident in the above Table 1, there is no one best way of paving that would mitigate UHI as well as provide runoff reduction, provided that cool pavement technologies are still under development (Synnefa *et al*., 2011), unlike cool roof strategies. On the other hand, pavement systemsare highly reliant on site specific conditions regarding their cool performance (Kevern *et al*., 2009), and the subbase and subgrade conditions of the pavement system, as well as the soil properties of the installation.

3. URBAN HEAT ISLAND EFFECT IN COLOMBO, SRI LANKA

Colombo, Sri Lanka, is a metropolis located near equator, generally having tropical climatic conditions where temperatures remain relatively high with humid conditions (i.e. warm humid) (Halwatura, 2008). Colombo is blessed with 2,623.5 hours of mean annual sunshine and 2,523.7mm of annual mean precipitation with over 145 average annual precipitation days (World Meteorological Organization (WMO), 2013). Colombo and its suburbs are on a steady development course resulting in increased changes to the land cover, which has its toll on the urban micro climate.

Even so, the Colombo still holds shades of green as opposing to its sister cities like Shanghai or Saint Petersburg. In the heat waves preceding monsoon seasons Colombo faces high outdoor temperatures which is intensified by the city to create urban heat islands. Nonetheless, Colombo city has not fully undergone an irreversible transformation into a concrete forest like many business cities around the globe. However, in the work of Silva (2004) who held, with reference to Sri Lankan urban climatic data, that Colombo has provoked deep changes in thermal energy balance, which indicates a growing UHI problem that create unpleasant microclimatic conditions at the pedestrian level.

Other regional tropical cities like Kuala Lumpur, Bangkok, and Jakarta have documented the micro climatic changes due to rapid urbanization, which bringing about increased urban heat, atmospheric pollution (with dust and pollutants) and reduced humidity as indicated by Sham and Jamaluddin (as cited in Sarat and Eusuf, 2011). Cities like Houston (Hitchcock, 2004) or Chicago (Chicago Department of Transportation, 2007) are facing the full wrath of the UHIE, which is literally costing the cities millions of dollars annually, in related expenses of enduring and mitigating UHI. These cities are reacting upon repercussions of what they have done to their environment and are desperately trying to amend for their deeds, whereas in the case of Colombo still the city of Colombo has time to act proactively to incorporate sustainability features to the town planning and development master plans. This may ensure that future of Colombo will be sustainable with minimal environmental detriments and related socio-economic implications.

UHI in Colombo has been studied by several authors, each focusing on different mitigation strategies such as; urban physical elements (Bandara, 2003), green roofs (Wijerathne and Halwatura, 2012) and tree shades and urban canopy Silva (2004). However, pavements structures with passive cooling effects in mitigating UHI are a potential research area that has still not yet been explored.

4. DISCUSSION

It is established that the pavement design and materials selection can be exploited to significantly reduce the environmental impact of urban development, and that it can greatly reduce substantial cost impacts in the maintenance phase in the life cycle of pavement systems (Muga *et al*., 2009).

A cooler pavement inherently reduces its surface temperatures and the heat stress on the pavement itself. Laboratory tests have found that cooler pavements may be considerably more durable against rutting and embrittlement (Pomerantz *et al*., 2000) ensuring increased lifetime of the pavement, which in turn is a potential cost saving. In addition to the environmental benefits, cooler roads and pavements can be cheaper to construct, and may also last considerably longer (Pomerantz and Akbari, 1998). On the ultimate end, the lifecycle costs of maintenance, rework and disposal of pavements will be reduced.

It was established that highly reflective pavement surfaces are a basic approach of cool pavements (Li, Harvey and Kendall, 2013). Highly reflective pavements offer an additional benefit of enhancing night illumination from light reflected off the pavement, amounting to less energy demand on night time roadside illumination. Pomerantz *et al*. (2000) suggests that enhanced visibility due to reflective pavements will help avoid accidents and reduce the costs of automobile insurance, whilst probably reducing auto theft and other street crimes. On the other hand, cool pavements directly affect the energy demand of a building by affecting the outside temperature as argued earlier in this paper. Altogether, more reflective, cooler pavements are capable of presenting a significant reduction in the huge expenditures on the nation's roads and cities.

Brattebo and Booth (2003) claim that permeable pavement compares extremely well in surface durability, infiltration capacity and water quality performance against classic asphalt. Therefore, as a strategy for storm water management and to control urban runoff water, permeable pavements have a wider role other than their assistance in mitigating UHIE. However, Brattebo and Booth (2003) claims although due to windblown dust or particulate matter washed off from storm water, permeability of pavements may reduce over time; the infiltration capacity does not fall drastically, suggesting the long-term permeability performance may not be problematic. Similarly, Gilberta and Clausen (2006) notes that even with decreased infiltration, the use of concrete pavers is preferable over traditional asphalt for control of nonpoint source pollution. However, it is noteworthy that a generalization of good performance cannot be guaranteed in every instance as permeability relies on many factors which are unique to each installation.

Obla (2007) agrees that permeable pavements assist sustainable development. He points out that it acts as a filter for pollutants, where the pavements capture the first flush of rainfall which will lead to the runoff of most pollutants, allowing pollutants to be percolated into the ground where soil chemistry and biology treats the polluted water. Obla suggests that pervious pavers function like a storm water retention basin and allowing the storm water to infiltrate the soil over a large area, facilitating local groundwater recharge. These benefits lead to more effective land use.

An important fact to consider while considering cool pavement strategies is the essential "trade-off" between pavements' thermal, permeability and structural characteristics. With reference to Table 1 it can be seen that high permeability does not necessarily mean high impact on UHIE. Even so, it has its merits as high storm water infiltration and as a pollution inhibitor. Meanwhile, increased perviousness has an adverse impact on the structural integrity; thus, limiting its strength. Conversely, alternatives with high albedo and low permeability maybe more efficient in mitigating UHIE and may withstand large compressive forces. However, environmental performance of such a system may not be sufficient for a sustainable built environment which demands a more holistic approach. Therefore, while suggesting for the incorporation of cool pavements as a driver for sustainability in the rapidly urbanizing Colombo and its suburbs this trade-off has to be found and compromises be made according to site-specific conditions.

The implementation of urban heat island mitigation strategies such as cooler pavement initiatives is primarily conditioned on receiving the necessary governmental and local community support. The difficulty in implementing cooler pavements is in taking a holistic view at the situation where most often without regard for the shortened lifetime of hot pavements or the heat-island effect; decisions are made on the basis of initial cost (Akbari, 2008). If these are taken into account, as studied by Ting *et al*. (2001) the life-time costs of cooler pavements may be lower for many kinds of pavements. Strategies for effective implementation may include: Green Building standards or rating systems, incentive schemes for voluntary actions and most effectively through inculcating these strategies into zoning, building and energy codes of the country.

5. FURTHER RESEARCH

The adverse social, environmental and economic issues of urbanization are manifesting in many forms from which urban heat island effect carries heavy significance. This paper discussed an overview of the issue and proposed a mitigation strategy based on existing literature. However, city-wide implementation of such strategies is still far from reality for Colombo due to various reasons.

The approach to overcome these constraints is through extended research and development, which will be the overall key to a sustainable city. Therefore, new alternative pavement systems with possible composite materials as greener building materials should be explored. Further studies needs to be carried out focusing on the thermal characteristics of pavement systems in local tropical climatic conditions. These studies should be extended to include permeability characteristics of pavement systems as well. In that sense research should also be focused on short term and long term effects of contaminants and clogging or pervious pavements in the local context.

However, extensive studies must be carried out on the costs and benefits of cool pavements as well as their durability, longevity and life cycle costs and life cycle environmental aspects. These studies shall be the base for studies on the self-sustainability of new cool pavement systems.

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COPING WITH ETHICAL DILEMMAS IN A SOCIALLY RESPONSIBLE MANNER - QUANTITY SURVEYORS' PERSPECTIVE

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ABSTRACT

Ethics is a vital constituent for any profession. Therefore, professions are governed via codes of practice published by respective professional bodies as a measure of ensuring compliance of members with professional ethics. These codes necessarily reflect social interests. Recognized professional organizations with regards to Quantity Surveying profession (RICS, AIQS, IQSSL, etc.) have introduced Codes of Professional Conduct which define the standard of professional conduct to which the members must adhere as socially responsible individuals. In a context these codes have not been successfully ableto achieve comprehensive social responsibility within the practice of respective members, this study attempts to understand the grounds for ethical/unethical behaviour, ethical dilemmas and action taken by QSs in the face of an ethical dilemma within professional practice. Frequent ethical dilemmas as well as contemporary developments, such as the predicament brought in by sustainability concept, have been identified by the study to be elements that need addressing. Findings of the literature review exhibit conclusive evidence about a strong relationship among QSs' practical execution; and knowledge and experience. The study concludes with an emphasis on the need for improving education and discussion of ethics as well as social responsibility necessitated by the broader society.

Keywords: *Ethical Dilemma; Ethics; Quantity Surveying; Social Responsibility; Sustainability.*

1. INTRODUCTION

A profession entails the implementation of a body of unique, expert knowledge (Fellows, 2003). Professions Australia (1997, para. 2) stated that "it is inherent in the definition of a profession that a code of ethics governs the activities of each profession. Such codes require behaviour and practice beyond the personal moral obligations of an individual". The same applies to Quantity Surveying profession.

Ethical codes have been widely illustrated by MacIver (1955) as indicators of appropriate behaviour among members of a group plus between the group as a whole and outsiders. Therefore, adherence to codes of ethics/conduct is ultimately in the best interest of the society. Codes of conduct/ethics have been published by many international professional bodies including Royal Institution of Chartered Surveyors (RICS) and Australian Institute of Quantity Surveyors (AIQS) to provide guidance to individual members who are responsible and accountable for their professions (AIQS, 2010; RICS, 2007). The Institute of Quantity Surveyors Sri Lanka (IQSSL), has also introduced a Code of Conduct for Quantity Surveyors practicing in Sri Lanka which represents the standard of professional conduct to which the members of the IQSSL need to adhere (IQSSL, 2007).

However, Henry (as cited in Fellows, 2003) cautioned that codes of ethics, alone, do not solve ethical dilemmas although they do aid in raising levels of awareness and thereby encourage ethical practice. Cartlidge (2011, p.124) defined an ethical dilemma as "a situation in which two or more deeply held values come into conflict. In these situations, the correct ethical choice may be unclear". Therefore, it is important to identify the most appropriate policy to be followed in coping with ethical dilemmas.

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Fellows (2003) identified that practice of ethics relates to the level of knowledge required and the practices of using that knowledge. Findings of many researchers (Christabel, Vincent, and Fan, 2001; Fan, Ho, and Ng, 2001; Ofori and Toor, 2009; Rathnayake, 2006) agree with Fellows (2003).

However, there are still many controversial arguments on this aspect of dealing with ethical dilemma. Therefore, this research is aimed at identifying the origins of ethical dilemmas and the determinants of coping with ethical dilemmas in a socially responsible manner.

2. QUANTITY SURVEYING PROFESSION/PROFESSIONAL

Quantity Surveying – a sub-discipline of surveying, becoming distinguished in the 17^{th} century subsequent to the Great Fire of London, had emerged as a distinctive profession only after extensive development throughout several centuries starting from as early as 16^{th} century (Thompson, 1968). Thompson (1968) described that during the 19^{th} century Quantity Surveying had evolved into an organized profession concurrently to establishment of professional institutions.

Steenderen and Hutton (2008) defined that "a Quantity Surveyor (QS) is a professional person who is skilled in calculating and managing the costs of a building project before and during construction" (p.293). Association of Graduate Career Advisory Services (AGCAS) Editors (2012) agreed with Steenderen and Hutton (2008) stating that Quantity Surveying profession encompasses a variety of duties related to cost aspects of construction projects including many advisory responsibilities. Several other authors (Lee, Trench, and Willis, 2011; Smyth, 2011) also stated that Quantity Surveying profession entails functions related to contractual management, procurement and cost management.

The above opinions (AGCAS Editors, 2012; Smyth, 2011; Steenderen and Hutton, 2008; Thompson, 1968) comprehensively conclude that Quantity Surveying is a 'Profession' and Quantity Surveyor is a 'Professional'.

3. ETHICS AND PROFESSIONS/PROFESSIONALS

Description to a 'professional' prior to institutionalization had been as follows:

> The professional man necessarily becomes his client's agent, acting on his behalf in matters of great moral, physical, or financial importance, often in ways whose validity or purpose the layman has no means of judging for himself, and it becomes of vital importance that a client should have a reasonable assurance that it is prudent to surrender control of important sections of his affairs, and that his agent will be honest, reliable and incorruptible (Thompson, 1968, p. 148).

Indirect implication of Thompson (1968) is that although it is not explicitly mentioned, professionals had been expected to be ethical in every aspect of their conduct. However, most of contemporary professionals serve and represent business organizations rather than themselves. McNaughton (as cited in Greenhalgh, 1997) held that professional education is incomplete without educating potential professionals of practical ethics and moral theory.

Follett (as cited in Martin and Shell, 1988) defined a professional as one who maintains a loyalty to a code of ethics and, thus, very few employees would qualify to be identified as 'professional'. Professions Australia (1997) held strongly that adherence to a code of ethics set up by respective professional bodies is a must for a profession. The latest definition to profession is "occupation, practice, or vocation requiring mastery of a complex set of knowledge and skills through formal education and practical experience. Every organized profession is governed by its respective professional body" (BusinessDictionary.com, 2013).

Over the years, definitions to the elements profession and professional have been woven around qualifications, competence and knowledge. On the other hand, ethics and adherence to codes of ethics have been associated consistently with the definitions of 'profession' as well as 'professional'. The definition of BusinessDictionary.com (2013) implies the same since professional bodies require members to adhere to codes of ethics. Therefore, ethics are imperative as far as a profession is concerned. If ethics are absent an occupation is not a profession and a worker is not a professional.

4. ETHICS VS. MORALS

The term 'moral' is manifestly associated with discussions on ethics. Yet, the scholars exhibit a vague use of it in the subject of ethics. Therefore, it would be ideal to discover the relationship between the phenomena 'ethics' and 'morals' attempting to avoid ambiguity. According to Garber, (2008) ethics are a more formalized set of standards established by the society or an organization to serve as guiding principles during decision-making and action-taking whereas morals are more personalized and internalized. Garber (2008) stood that an organization's ethics should be consistent with the moral standards of its members and the external society.

Morals are humane values held deep in the thought process of humans (Shaw, 2011). Morals may vary from person to person and from society to society although moral principles often overlap owing to the phenomenon of shared justification of interest in social wellbeing (Shaw, 2011). Shaw further noted that, in some cases, morals of individuals may not be in the best interest of the society and focus majorly on personal benefits.

However, many researchers and authors (Dabson, Plimmer, Kenney, and Waters, 2007; Garber, 2008; Shaw, 2011) unanimously agree that ethics are based on moral values and principles of human beings. Therefore, in order to maintain the clarity of factual findings morals are deemed to be good for the purpose of this research.

5. ETHICS

Ethics are a personal statement of morals and they relate to the environment in which they have evolved (Greenhalgh, 1997). Heller (as cited in Greenhalgh, 1997) defined ethics: "Ethics is the condition of the world. Chemical substances or organisms can exist without ethics, but there is no world without ethics. 'Worlds' is not the sum total of lifeless and living things but the meaning of all those things…" (p. 223). Although, ethics are intangible and may, sometimes, not be explicit, ethics are essential to safeguard the spirit of humanity.

Greenhalgh (1997) held that ethics are continuously evolving and moral values tend to change over the time. It must have been the basis of statement made by Fewings (2008) that there has been extensive debate over definition for ethics and ethical behaviour throughout the history and it is very difficult to provide precise definitions to both phenomena. However, human sense of good and bad and right and wrong is the basis for ethics according to Fewings (2008).

The more contemporary and scientific explanations of ethics reiterate that 'good' constitute ethics. The Journal of Business Ethics (as cited in Fewings, 2009) describes ethics as "all human actions aimed at securing a good life" (p. 1). Shaw (2011) contended that "Ethics deal with individual character and the moral rules that govern and limit our conduct. It investigates questions of right and wrong, duty and obligation, and moral responsibility" (p. 9).

Everingham (as cited in Wickramasinghe, 2012) revealed that ethics is generally concerned with human behaviour and categorized ethics into three categories, based on findings of researchers in the field of construction, as follows:

- Personal ethics
- Business ethics
- Professional ethics

Ethics itself is a personal phenomenon (Fellows, 2003). Cartlidge (2011) agreed by establishing that "Ethical behaviour is developed by people through their physical, emotional and cognitive abilities. People learn ethical behaviour from families, friends, experiences, religious beliefs, educational institutions and the media" (p. 123).

A study by Vee and Skitmore (2003) revealed that the general perception in the construction industry and, arguably, in the society at large is that business ethics should not take precedence over personal ethics and it is believed that personal ethics should drive business ethics.

Professional ethics concerns the morality of the behaviour of professionals in their day-to-day practice and it ascribes moral responsibility to professionals practising in a particular profession (Fan et al., 2001).The core purpose of professional ethics is to guarantee that unfair advantage is not taken by the expert over the lay person due to the knowledge gap – 'customer protection' through professional self-regulation (Fellows, 2003). Dabson et al. (2007) further held the following:

> Professional ethics must be viewed from the point of view of the individual professional, who is required to make ethical decisions; from the professional association which expects an ethical stance from its membership, and seeks to regulate and benefit from their ethical behaviour; and of the employer organisation which both influences and is influenced by the ethical principles of its professional employees (p. 12).

Vee and Skitmore (as cited in Fewings, 2009) held that professional ethics are driven by personal ethics. Conclusively, scholars in the field (Cartlidge, 2011; Dabson et al., 2007; Edwards and Pottinger, 2010; Fellows, 2003; Fewings, 2009; Vee and Skitmore, 2003) collectively maintain that ultimately it is at the discretion of the individual person to make the final judgement based on personal ethics – personal values and beliefs. Ethical theories further sustain the argument.

5.1. Ethical Theories

According to (Wickramasinghe, 2012) ethical theories have been developed in attempt to answer the questions:

- How people ought to behave?
- What kinds of acts are moral?

Ethical theories, namely, 'Consequential theories' and 'Deontological theories', have evolved from modified criteria developed by ethical thinkers and philosophers for assessing the morality of human decision-making and searching for the bases of morality (Fan *et al.,* as cited in Wickramasinghe, 2012).

1. Consequential Theories

According to Fan et al. (as cited in Wickramasinghe, 2012) consequential theories (i.e. Egoism and Utilitarianism) examine consequences of an action which predict the actions of an individual in a way that minimizes or maximizes individual or social benefits. The following table summarizes the attributes of Egoism and Utilitarianism:

Table 1: Attributes of Consequential Theories (adopted from Fan et al., as cited in Wickramasinghe, 2012)

Theory	Focus	Judgement of Behaviour
Egoism	Individual good (self-love and self-interest)	The individual's self-interest and values are the deciding factors for judging behaviour.
Utilitarianism	Social good (greatest good for the greatest number)	Act utilitarianism – maximization of happiness in performing an act Rule utilitarianism – tests whether an act would end up in more happiness than unhappiness

2. Deontological Theories

As described by Fan *et al.* (as cited in Wickramasinghe, 2012):

> Deontological theories are the non-consequential theories which look at the means of arriving at ethical decisions. Theory of rights, theory of duty, theory of justice and categorical imperativeness are examples for this. In the 1600s, Shaftesbury laid the foundation for the theory of rights and explained the origin of the moral conceptions. Subsequent advocates of moral rights classified the fundamental rights of humans into different branches as the right to free consent, the right to privacy, the right to freedom of conscience, the right of free speech (p. 12).

6. CODES OF PROFESSIONAL ETHICS/CONDUCT

Chalkey (as cited in Greenhalgh, 1997) quoted the Ormrod Committee Report on Legal Education of 1971 in an attempt to describe the function of codes:

> A self-imposed code of ethics is intended to correct the imbalance in the relationship between the professional man and his client and resolve the inevitable conflicts between the interests of the client and the professional man or the community at large (p. 260).

Deinhart (as cited in Dabson *et al.,* 2007) argued, with a different perspective, that codes do not and cannot do anything to change the behaviour of those whose actions and standards are inappropriate and those whose behaviour is entirely appropriate do not need a code anyway. View of Deinhart (as cited in Dabson *et al.,* 2007) again directs towards the phenomenon that the individual person holds the key for ethical behaviour regardless of the presence of codes, although codes are effective drivers.

7. SOCIAL RESPONSIBILITY THROUGH CODES OF ETHICS/CONDUCT

Many scholars in the field of professionalism (Dzur, 2010; Shamoo and Resnik, 2009; Wilding, 1982), during different times, have held a similar opinion with regards to the 'social responsibility' vested in professions as well as professionals by means of Codes of Conduct and expectations of the society as a whole.

According to Wilding (1982) "Accountability to individual clients is only one part of genuine professional responsibility and that can only be adequately achieved through a broader notion of social responsibility" (p. 130). Shamoo and Resnik (2009) remarked that "professions have codes of ethics to achieve self-regulation and promote social responsibility" (p. 10).

Professional Codes justly comply the opinions of above researchers (Dzur, 2010; Shamoo and Resnik, 2009; Wilding, 1982), about social responsibility, i.e. "A Member should be guided as much by the spirit of the Rules as by the express terms" (RICS, 2007, p. 4); "Members, partnerships or corporations shall maintain a high professional standard, be of good fame, integrity and character" (AIQS, 2010, Section 3); "Quantity Surveyors shall always act so as to uphold and enhance the honour, integrity and dignity of the profession while safeguarding public interest at all times….." (IQSSL, 2007, p.2).

Dzur (2010) maintained that professionals surpass self-interested economic rationality and are primarily oriented in the community interest rather than in individual interest. On the other hand, Dzur (2010) justified social expectations stating that "The larger society can rightly expect that the influential knowledge and skills of professionals serve social purposes, especially since professions are granted significant leeway in regulating their own conduct" (p. 46). As much as society expects professionals to be socially responsible they are put under close scrutiny by the codes in terms of social responsibility.

8. ETHICAL DILEMMAS

According to Fewings (2009) an ethical dilemma involves choosing between two or more imperfect alternatives – outcomes are likely to affect people in different ways and there is a need to apply some discretion and judgement based on the experience and other criteria. Shaw (2011) contended that an ethical disagreement does not imply that all opinions are correct; it would leave an individual in a dilemma forcing him or her to choose one side.

However, the scholars (Cartlidge, 2011; Fewings, 2009; Shaw, 2011) have not demonstrated explicitly that two or more valued choices are open for an individual facing an ethical dilemma. An ethical dilemma needs to be considered necessarily as a situation that demands the choice of better one from two good options rather than choosing the good one from a mix of good and bad options. Accordingly, ethical dilemmas require to be recognised as positive occurrences. Decision made in the face of dilemma will be attributable to individual characteristics.

8.1. Ethical Dilemmas Faced by Quantity Surveyors

According to Herkert (1999) Ethical dilemmas faced by Engineers have been identified to be related to: Public safety and welfare; Risk and the principle of informed consent; Conflict of interest; Integrity of data and representation of it; Whistleblowing; Choice of a job; Accountability to clients; Plagiarism and giving credit where due; Trade secrets and industrial espionage; Gift giving and bribes; and Fair treatment.

However, the most frequent ethical dilemma experienced by QSs involve acceptance of hospitality or gifts from the contractors, subcontractors and clients (Cartlidge, 2011).

Rathnayake (2006) identified several ethical dilemmas faced by the QSs in Sri Lankan context of which attempts taken by the Bidders to influence the Consultants being the most critical and frequent. Following are the other ethical dilemmas faced by QSs (Rathnayake, 2006): Collusive tendering; Favouritism in awarding tenders and evaluating tenders; and Drafting vendor oriented specifications. However, those phenomena discovered by Rathnayake (2006) fall behind the definition of ethical dilemmas as most of the discussed issues do not present individuals with two ethically desirable ends.

Ofori and Toor (2009) brought up a newer development of ethical concern for QSs – sustainability vs. face cost, to go beyond their present focus on cost to provide leadership in the area of overall economic viability of construction that incorporates the concept of ‘sustainability’. With much emphasis being placed on sustainable construction (Cartlidge, 2011), in order to mitigate inevitable consequences of energy and environmental crises, dilemma of sustainability vs. cost is likely to occur frequently. However, this particular type of dilemmas has been hardly addressed by the existing research literature.

8.2. Origins of Ethical Dilemmas – Professional Perspective

Fewings (2009) believed that personal ethics are highly prone to clashing with company policy. In approval of that, Shaw (2011) identified that several aspects of corporate structure and function force the professionals to supress individual moral responsibilities. The following specific elements limit the individual integrity of professionals serving in business organizations (Shaw, 2011):

1. Organizational norms

Norms of business organizations, at least the greater portion of them, have been derived from profit oriented goals of the organizations. What the society expects from ethical persons is contrary to what is expected by the organization from efficient, profit-minded members of the organization. Joseph, Badaracco and Webb (as cited in Shaw, 2011) had also confirmed the validity of the argument.

2. Pressure to conform (groupthink)

Extreme conformity to the group individuals work in lead to groupthink. When there is pressure for concord within a solidly bound group overpowering desire or ability, to appraise situation realistically and take alternative courses, of its members ‘groupthink’ occurs. Organizational norms contribute to groupthink to an extent and these two phenomena ultimately lead to the surrender of individual moral autonomy.

3. Diffusion of responsibility

Responsibility is fragmented and diffused throughout an organization across different levels – vertically and horizontally. Due to participation of many people, single individuals are highly unlikely see himself or herself responsible for what the organization is doing. Individuals tend to disregard their accountability owing to the fact that individuals have no control over the organization's dealings as a cohesive whole.

Shaw (2011) argued, about adhering to professional codes, that it is ultimately the individual who should decide on which morals to stand by:

> Conformity with our considered moral beliefs is an important consideration in evaluating moral principles. A considered moral belief is one held only after we have made a conscientious effort to be conceptually clear, to acquire all relevant information, and to think rationally, impartially, and dispassionately about the belief and its implications. We should doubt any moral principle that clashes with many of our considered beliefs (p. 35).

Implication of Shaw (2011) is that professional codes, themselves, can stimulate ethical dilemmas if they come into disagreement with personal ethics as well as clashing personal beliefs.

However, as personal variables – knowledge, perception and moral values – determine the personal ethics and it is personal ethics that eventually influence the individual professionals, as identified earlier by this paper, potential of inducing an ethical dilemma is held by personal variables themselves. If only knowledge, attitudes and values of the individual stand against organizational policy/ethics there will be ethical dilemmas. The indirect implication suggests that to face with an ethical dilemma one has to possess sufficient knowledge and socially responsible moral values.

Ultimately, an ethical dilemma is not a bad thing. Only a socially sensible and morally sound person is likely to face with ethical dilemmas. Naturally, such a person can be strongly anticipated to make the best possible choice in response.

8.3. Responding to Ethical Dilemmas

Garber (2008) held that each individual has a 'moral compass' that directs and helps individuals through moral dilemmas in daily lives. There exists a personal code of ethics for all individuals, drafted based on past experience and lessons learnt, and decisions made in response to dilemmas reflect the influences and expectations of those who are important to the individuals as well as the personal code (Garber, 2008).

Kohlberg (as cited in Fewings, 2008) came up with a theory categorizing why people make decisions. Kohlberg believed that there were three levels of moral reasoning and six stages of development with an irreversible development of approach, depending on personal values of the individuals, through the stages from one to six (Table 2).

Table 2: Kohlberg's Stages of Moral Reasoning (Fewings, 2009)

Level	Focus	Stage	Orientation
Pre-conventional morality	Self-interest	1	Avoiding punishment or harm
		2	Self-interest and individualism
Conventional morality	Community interest	3	Community norms + relationships
		4	Maintaining social order
Post-conventional morality	Universal justice	5	Just rules and consensus
		6	Universal principles – autonomous

Shaw (2011) emphasized the importance of adhering to the codes of conduct for respective professions and declared that individuals carry responsibility to assess whether they are consistent with the morals of the individual in case of ethical dilemma.

Ho (2011) reviewed ethical decision making model which had been proposed by scholars in the field of ethical philosophy (Table 3):

Table 3: Ethical Decision-Making Models (Ho, 2011)

Decision Making Model	**Source (as cited in Ho, 2011)**
Four-component ethical decision-making model	Rest (1986)
Contingency model	Ferrell and Gresham (1985)
Person-situation interactionist model	Trevino (1986)
Behavioural model	Bommer et al. (1987)
Integrative model	Stead et al. (1990)
Issue contingent model	Jones (1991)
Social network model	Brass et al. (1998)
General ethical decision-making model	Wittmer (2005)

Ho (2011) stood that all ethical decision-making models construct decision-making based upon three sets of variables:

1. Individuals
2. Situational/Organizational
3. Moral intensity

The researchers (Fewings, 2009; Garber, 2008; Ho, 2011; Shaw, 2011) conclusively agree that as much as personal variable determine ethical behaviour of individuals and cause ethical dilemmas, personal variable are decisive in determining the course of action an individual professional would make in the face of an ethical dilemma.

8.4. KNOWLEDGE AND EXPERIENCE VS. ETHICS AND ETHICAL DILEMMAS

According to Fan *et al.* (2001) QSs consider that professional ethics reading materials enhance their professional image and help in addressing and providing a working guideline for solving major ethical problems. The same study (Fan *et al.,* 2001) concluded urging the need for the introduction of courses in professional ethics standards helping professionals to resolve ethical dilemmas during day-to-day practice.

Christabel *et al.* (2001) came up with a discrepancy in the standards of professional ethics between senior and junior surveyors and found that there exist wide and significant variances towards ethical concepts and decision-making considerations between senior and young practitioners. Christabel and Vincent (2003), in a subsequent study, confirmed that the more experienced and higher educated the QSs are the more they are willing to sacrifice their self-interests for the sake of social good when facing ethical dilemmas. Fellows (2003), in agreement, established that ethics relates to the level of knowledge required and the practices of using that knowledge. Rathnayake (2006) confirmed the same for Sri Lankan QSs.

Ho (2008) concluded, based on results of a case-study research conducted to study the ethical behaviours of QSs, that there is a significant impact of education and experience on the attitude of QSs towards sacrificing their self-interest for the greater good and it was found that more junior QSs place more emphasis on duty whereas more senior professionals are more concerned about process and consequence. Results of Ofori and Toor (2009) agreed with those of Ho (2008) copiously. This strongly implies that knowledge can inculcate positive morals – behavioural change in individuals for good, making them face ethical dilemmas and necessarily make the sensible choice.

9. CONCLUSIONS

Adherence to Codes of Conduct/Ethics is unavoidably associated with professions and practitioners of professions – the professionals. The profession and professionals of Quantity Surveying are no different in that sense. Professional bodies world over have introduced Codes of Professional Ethics/Conduct as a means of regulating their members and providing guidance. Professional persons, as individuals, have their own value systems and personal ethics – thinking patterns and morality. They make decisions about ethically right and wrong based on their personal variables – values, beliefs, experience and knowledge. Personal ethics tend to associate social responsibility. Professional Codes further assist individuals to determine whether they are acting morally or with social responsibly.

Professionals can face ethical dilemmas due to conflicting values: company policy clashing with personal ethics, clashing personal values or moral principles, and Professional Codes clashing with personal beliefs. An ethical dilemma necessarily involves personal values contradicting with external elements. Knowledge and experience play obvious roles in inducing ethical dilemmas as personal morality, perception and rationality evolve corresponding to personal lessons learnt. As far as ethical dilemmas faced by QSs are concerned, sustainability vs. cost is a new development alongside more frequent cases of conflict of interest, influence through bribery/gift, etc.

As much as knowledge and experience play roles in stimulating ethical dilemmas, they provide the basis for coping with ethical dilemmas in a socially responsible manner. This is prominent as far as research findings in the subject are concerned – senior professionals are noticeably ahead in coping with ethical dilemmas in socially responsible way as well as prioritizing social wellbeing within their conduct.

Conclusive implication is that education, research and open discussion, in terms ofethics, social good, sustainability, etc., need improvement so as to instil social-interest and social responsibility into value system and thought process of Quantity Surveying professionals. Thus, ethical dilemmas would be coped with a higher degree of social responsibility.

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DEVELOPING A FRAMEWORK FOR SELECTION OF SUSTAINABLE MATERIALS BASED ON THE EMBEDDED ENERGY FOR BUILDING CONSTRUCTION

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ABSTRACT

Material selection in conventional construction projects concentrate on various criteria. However, sustainable construction must take into account of embodied energy of materials during material selection which is rarely addressed by construction professionals. Analysis of embodied energy of construction materials is important as increase in energy consumption will indirectly trigger a series of collisions leading to instability of the environment. Therefore, this research study aims at developing a framework for selection of materials based on embodied energy and other identified main parameters. The study was carried out based on figures retrieved from literature survey as well as on the perceptions of professionals involved in construction through questionnaire survey. The study categorized the identified significant materials based on five major elements (foundation, wall, roof, floor finishes and doors &windows) with two materials per each and evaluated their performance based on the parameters of embodied energy, price, durability and maintainability. According to empirical findings, most of the selected materials of the same element have performed in similar manner on the selected parameter. However, in some selected materials the results for embodied energy has a significant difference with their counterparts which had an impact on the overall score of those materials. Further, even though embodied energy parameter ranked last in the importance weightings, the parameter is of acceptable significance which can have a huge impact on material selection. Ultimately, framework for material selection was developed with the aid of research findings which comprises of four combinations of each of the selected materials with each other in terms of their performance on each individual parameter and on overall performance.

Keywords: *Embodied Energy; Material Selection; Sustainable Construction.*

1. INTRODUCTION

The increased number of construction activities worldwide has effected severely on the stability of the environment. This has led to the enhanced concern of the protection of environment in which construction activities takes place where sustainable construction has been hailed as a way forward to eradicate adverse impacts on environment (Hussein, 2009). Though there is no agreement as to what is meant by sustainability it has been interpreted as ensuring adoption and maintenance of communities and local organizations to cope with future challenges while achieving set objectives (Bracht *et al*., 1994). Abenayake (2010) describes sustainable buildings as energy and environmentally efficient buildings, providing economic, environmental and social benefits over the whole building environment, while protecting and improving the needs of future generation.

Sustainability in built environment has been the choice of most architects, developers as well as authorities all across the world in order to tackle the environmental impact (Mastor, 2008). According to Grace (2006), there are so many environment assessment methods available to evaluate the environment sustainability of the project. In context of the alarming rate of energy consumed in

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various sectors, building designs apart from their structural and functional requirements also need to be planned and designed for energy conservation (Krishnakedar, 2006).

2. LITERATURE REVIEW

2.2. EFFECT OF BUILDINGS IN ENVIRONMENTAL SUSTAINABILITY

Construction projects usually consume large amounts of materials, produce tons of waste and can involve the weighing of the preservation of historically significant structures against the strong desire for new and modern designs (Kheel, 1992). Therefore, according to Roper and Beard (2006) buildings and civil infrastructure are considered to be presenting a difficult challenge in the field of sustainability due to their profound impact upon the environment.

According to Carswell and Smith (2009), Schendler *et al*. (2008) and US Department of Energy (2007), the built environment accounts for nearly two-thirds of electricity consumption, over one-third of primary energy use and close to one-half of greenhouse gas emissions within the United States. Furthermore, Walker *et al*. (2007) has stated that the construction activity worldwide consumes 3 billion tons of raw materials annually. Buildings also consume a quarter of all the wood harvested as stated by Roper (2003 cited Roper and Beard, 2006) and are responsible for producing 50 percent of chlorofluorocarbons and indirectly 33 percent of CO_2 and 40 percent of the landfill waste (Walker *et al*., 2007).

Therefore, whether it is construction or operation, built environment has become a broader global concern, as buildings are major contributors to global environmental issues with consequent impacts on the natural environment. As discussed by Wyatt *et al*. (2000) and Newell (2008), organizations and specifically built environment professionals, themselves clearly have a role to play in the development of technology and innovations, if they are to sustain their business operation for the long-term. The greatest opportunity for an organisation to review the environmental performance of its built assets is at the initial design and procurement stages (Walker *et al*., 2007).

Thus, Walker *et al*. (2007) also suggests that more appropriate sustainable design solutions need to be developed, which reduce the use of raw materials and addresses the issues of future maintenance and replacement cycles, through to eventual decommissioning and disposal. Therefore better attention must be given as sustainable development is unattainable without sustainable buildings (Lai and Yik, 2006). Subsequently, a sustainable building or green building design focuses on increasing the efficiency of resource use while reducing building impacts on human health and the environment during the building's lifecycle through better design, construction, operation, maintenance, and removal (Wikipedia, 2009).

Typically, buildings are designed to meet building code requirements, whereas green building design challenges designers to go beyond the codes to improve overall building performance, and minimize life-cycle environmental impact and cost (Gowri, 2004). This has lead to the continuous assessment and monitoring from the planning/design stage up to the completion of construction, for declaring a building as a “green building” (Malarthamil, 2009). As a result several green building rating systems have been developed to objectively evaluate energy and environmental performance of built environments (Jayasinghe, 2010).

2.2. EMBODIED ENERGY

Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment (Wikipedia, 2009). Since construction materials use resources of a country, a proper selection of materials is thus important for sustainable development. Therefore assessment of environmental burdens associated with different construction materials used for buildings is necessary in order for decision-makers to select environmentally benign materials (Abeysundara *et al*., 2008).

Integration of several factors such as environmental, economic and social provides an overall picture of a material and thus, helps in selecting suitable materials for buildings through a multi-criteria decision-making approach (Abeysundara *et al*., 2007). Embodied energy is one such measure of the environmental impact related to construction materials (Commonwealth Scientific and Industrial Research Organization, 2008). According to Miller (2001), the term “embodied energy” is subject to various interpretations rendered by different authors and its published measurements are found to be quite unclear as all these definitions represent differences of opinion about the system boundaries to be included in embodied energy analysis. There are two ways in which embodied energy can be analysed: embodied energy of materials and embodied energy of building. This research focuses on embodied energy of materials only. Basically, the energy consumed in production (raw material extraction, transport, manufacture, installation) is called the “embodied energy” of the material and is the concern of energy consumption and carbon emissions (Dixit *et al*., 2010).

The Figure 1 represents the proportion of energy used by different industries where construction industry consumes high energy. Therefore, it is an important parameter for comparing materials or products in environmental terms (Menzies and Muneer, 2000). Proper accountability of embodied energy will contribute to data and information needed to create an energy economy that accounts for indirect and direct contributions (Dixit *et al*., 2010).

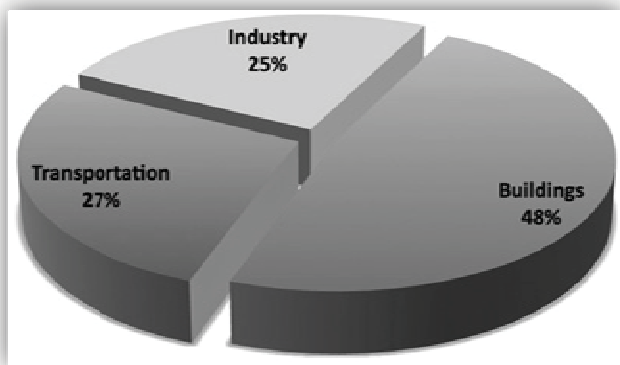

Figure 1: US Building Energy Use Comparison (Source: Cole and Kernan, 1996)

2.3. *SIGNIFICANCE OF EMBODIED ENERGY*

According to Crowther (1999) and Pullen *et al*. (2006), major endeavors for energy conservation assumed the operating energy of a building to be much higher than the embodied energy of a building. However, current research has disproven this assumption and found that embodied energy accounts for a significant proportion of total life cycle energy.

Embodied energy is expended once in the initial construction stage of a building, while operational energy accrues over the effective life of the building. Operational energy conservation could be accomplished more optimally with energy efficient appliances and advanced insulating materials, which are available more readily (Sartori and Hestnes, 2007). But embodied energy can only be reduced by preferring low energy intensive materials. Commonwealth Scientific and Industrial Research Organization (2008), has demonstrated that in developed countries, the embodied energy contained in a building is 20–50 times the annual operational energy needed for the building.

The building material production industry is responsible for 20 percent of the world's fuel consumption. Therefore, embodied energy results are critical for national and global strategic plans for energy (Tiwari, 2001). Consequently, a modest knowledge and awareness of the embodied energy contents of building materials could encourage the use of not only production and development of low embodied energy materials, but also their preference among construction design and industry to curb energy use and carbon dioxide discharge (Ding, 2004).

Due to the significance of embedded energy of materials, several green rating systems have also identified embedded energy as an important criterion in green certification.

2.4. *EMBEDDED ENERGY IN GREEN BUILDING RATING SYSTEMS*

As discussed earlier, green buildings have become a flagship of sustainable development, several green building rating systems have been developed to objectively evaluate energy and environmental performance of the so-called green built environments. Since these rating systems are employed for construction works throughout the world for evaluation of sustainability, it would be beneficial to identify the recognition given to embodied energy in them. Therefore, the embodied energy significance in green building rating systems of developed countries, namely LEED and BREEAM and Sri Lankan GREEN^{SL} are discussed here.

LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN – NEW CONSTRUCTIONS (LEED-NC) – UNITED STATES

The LEED rating system attempts to balance the need to reduce both embodied energy and operating energy of buildings. Whether a new or renovated building, LEED encourages reduction in embodied energy through;

- Use of salvaged and recycled content
- Re-use of materials
- Construction waste management
- Reduce transport impact by use of regional and rapidly renewable materials
- Providing points for designing building durability

(Carpenter, 2010)

BUILDING RESEARCH ESTABLISHMENT ENVIRONMENTAL ASSESSMENT METHOD (BREEAM) – UNITED KINGDOM

According to Building Research Establishment (2009), BREEAM identifies that it is important not only to consider the raw materials used but also the embodied energy used to create each element in a building.

BREEAM does this by rewarding:

- Materials with a low embodied energy i.e. 'A' rated in the Green Guide to Specification
- Buildings where part or all of an existing building is being re-used (i.e. refurbishment projects)
- Responsibly resourced materials
- Use of recycled materials

(Building Research Establishment, 2009)

GREEN^{SL}RATING SYSTEM FOR BUILT ENVIRONMENT

The GREEN^{SL} rating system also attempts to reduce both embodied energy and operating energy of buildings through;

- Use of salvaged and recycled content
- Re-use of materials
- Construction waste management
- Reduce transport impact by use of regional and rapidly renewable materials
- Buildings where part or all of an existing building is being re-used
- Designing energy efficient buildings

(Green Building Council of Sri Lanka, 2011)

2.5. *SIGNIFICANCE OF EMBODIED ENERGY FOR MATERIAL SELECTION IN SRI LANKA*

Sustainable development should be the theme for all development projects as per Rio Declaration in 1992 of which Sri Lanka is a signatory country. Further, Sri Lanka has committed itself to the control of substances that deplete the ozone layer according to the Montreal Protocol of 1985 and the emissions of green house gases according to the Kyoto Protocol in 1997. In this context, assessment of environmental burdens associated with different construction materials used for buildings is compulsory for Sri Lanka (Abeysundara, 2008). But for the time being, above assessments are yet to be accounted in a proper manner.

Embodied energy is one way to measure the environmental impacts of construction. Since embodied energy concerns about the energy input for construction, it would be beneficial to identify the sources and types of energy used for various activities to study the impact and significance of energy in the Sri Lanka context.

The domestic sector and manufacturing industries in Sri Lanka mostly use electrical energy supplied by the national power supply which has a mix of electricity; mainly thermal (generated by burning oil) and hydro (Ceylon Electricity Board, 2008). For transport also, the major energy source is fossil fuel (i.e., gasoline or diesel). Therefore, it can be identified that, energy for manufacture of materials and building construction is mainly from fossil fuels.

According to United Nations Environment Program (2001), it is well known that with burning of fossil fuels, emissions are released to the environment and this may have a great potential for increasing global warming, acidification, nutrient enrichment, photochemical smog formation, etc. Out of the above, significant environmental impacts affecting the Sri Lanka are nutrient enrichment and acidification. Global warming may also have an effect, as Sri Lanka is an island in the Indian Ocean.

Based on the above discussions, increase in energy use of construction will indirectly trigger a series of collisions leading to instability of the environment in the island nation. Therefore by identifying and reducing the embodied energy for construction and materials, the impact of energy use on the environment can be reduced extensively.

Even though a specific guideline has been developed to cater the needs of the Sri Lankan construction industry, yet it has not been well established. Building professionals are also in confusion in terms of embodied energy. Therefore, a proper and well guided evaluation criterion is needed to be established for material selection if sustainable construction is to bloom more effectively within the local construction industry. Hence, this research aims at developing a framework for sustainable material selection based on embodied energy of materials.

3. METHODOLOGY

Construction of a building requires vast numbers of different types of resources in different quantities. Out of this vast number of resources, construction materials plays a vital role as they directly contributes to the physical existence of the structure. Therefore, it would be less feasible to identify and evaluate the embodied energy factor of each and every materials used for construction projects. To facilitate this research, it is necessary to identify the significant materials used in the construction industry today. In order to achieve this task, several similar construction projects were selected where, these projects will act as a sample to represent the total commercial construction projects in the Colombo district.

The basis for identifying the significant materials was by using input percentages identified for the calculation of price fluctuations. These input percentages are calculated for the project by considering the cost contribution of individual input to the construction project. Therefore these percentages can be identified as a rational and appropriate method for identifying the significant materials for construction.

The following table (Table 1) shows the major input percentages obtained from six construction projects. For the ease of clarification, the materials are sorted based on the descending average value of their input percentages to the project

Table 1 - Categorization of Significant Materials Based on Input Percentages

Material	**Project 1**	**Project 2**	**Project 3**	**Project 4**	**Project 5**	**Project 6**	***Average***
RF Steel	22.33	17.21	14.26	7.00	12.03	16.43	***14.88***
Cement	10.56	8.60	7.66	10.00	7.67	9.32	***8.97***
Aluminium Doors & Windows	5.17	6.32	5.27	0.50	18.72	9.73	***7.62***
Steel Work	1.07	3.03	5.72	18.00	0.10	6.39	***5.72***
Form work Planks	4.24	3.56	1.80	4.10	1.47	2.45	***2.94***
Sand	3.06	1.23	3.06	2.00	0.43	2.22	***2.00***
Floor tiles (Ceramic/Porcelain)	1.74	5.65	0.30	3.00	2.23	2.67	***2.60***
Clay roof tiles	2.26						***2.26***
Metal	3.41		2.48	3.00	0.03	2.04	***2.19***
Brick	3.14	1.72	1.52	6.00	0.59	0.03	***2.17***
Asbestos sheet roof		1.52		2.75			***2.14***
Timber Doors & Windows	3.61		1.95	0.90	0.01		***1.62***
Glass	0.00	1.11	0.14		5.51	0.19	***1.39***

Since identification of the embodied energy distribution deemed to be beneficial, consideration of embodied energy of materials based on major elements of the building structure will be more conversant. As a result, the significant materials identified earlier will be categorized based on several key elements of the buildings.

The categorization will consist of key material for the element along with alternatives for comparison. For this study to be feasible, the number of materials selected for further energy analysis as shown in Table 2, needed to be limited and certain elements will consist of material not based on the significance list but as commonly used materials for commercial construction in Sri Lanka. Table 3.2 also shows the comparison of embodied energy per Kg which were available through previous research articles.

Energy was credited during the calculations of embodied energy of material for timber as 60% firewood at the end of life. The energy of vinyl tiles was calculated by including offshore energies as Vinyl tiles have to be imported from India. Wire cut brick and hollow concrete blocks were considered for walls.

As this research aims at developing a framework for selection of sustainable material based on embodied energy views of various professional involved in the construction projects in Sri Lanka need to be evaluated. To aid that purpose, quantitative approach has been identified as the most suitable research approach. Quantitative approach tends to relate to positivism and seek to gather factual data. It studies relationships between facts and how such facts and relationships accord with theories and the findings of any research executed previously (Fellows and Lui, 2003).

Table 2 - Categorization of Significant Material Based on Building Elements Embodied Energy Comparisons

	MJ/Kg	MJ/m3 / MJ/m2
Foundation		
Rubble	0.37	712.00 MJ/m3
Concrete	0.95	1000.00 MJ/m3
Wall		
Brick	1.32	343.12 MJ/m2
Block	0.81	187.50 MJ/m2
Finishes (floor)		
Ceramic/Porcelain tile	9.00	11.83 MJ/m2
Vinyl Tile	79.09	97.99 MJ/m2
Doors and Windows		
Timber	1.80	360.00 MJ/m2
Aluminium	236.80	5470.00 MJ/m2
Roof		
Asbestos sheet	2.85	219.67 MJ/m2
Clay tile	27.76	91.87 MJ/m2

(Source: Abeysundara, 2008)

Data required for the research were collected using a "Questionnaire Survey". Evaluation of environmental sustainability will not be the only criterion in building up framework for materials material selection for the modern day buildings. Therefore, in addition to the embodied energy parameter, several other parameters had to be included to the evaluation process to make the outcome of this research both environmentally and economically sustainable considering the total life line of the construction project. Consequently, four parameters were selected to evaluate the performance of the materials which include;

- Embodied energy
- Price
- Durability
- Maintainability

Durability is the ability of materials to endure, while maintainability is the ease with which a material can be maintained. The questionnaire survey facilitated the respondents to perform pair wise comparisons on the selected parameters and to provide their judgment with regard to each selected materials performance considering each parameter. Analytical Hierarchical Process (AHP) Prioritization tool scoring methods was used for the pair wise evaluation of parameters while the respondents were required to give the credits as appropriate on a scale of 1 to 10 for the evaluation of material performance with regard to parameters.

The questionnaire considered the views of professionals, thus making the individual professional the subject or unit for analysis. The population for the study consisted of individuals pertaining to different professions relating to the field of construction. The questionnaire was distributed to thirty numbers of professionals, personally as well as via electronic mail out of which only twenty five responded.

Data collected through the questionnaire survey were analyzed in several stages. Firstly, AHP tools were used to analyze the data for prioritizing the parameters of material evaluation. Parallel to prioritization of parameters, the scores given to each material with regard to these parameters was evaluated by taking the mean values. Thereafter, the derived mean values were normalized to reduce redundancy and statistical errors.

Normalization of mean values was done by considering the performance of each parameter with regard to the element. Therefore, anomalies will be decomposed by considering the value of a certain materials performance with the regard to the performance of the same parameter on the alternative material of the same element in accordance with equation Eq: 01.

$$x = \frac{Xa}{Xa + Xb} \times 10$$

(Eq: 01)

x	-	Normalized mean value
Xa	-	Mean value of material
Xb	-	Mean value of alternative material

When it came to normalization of values for embodied energy, a slightly different equation had to be used as materials with high embodied energy required to be given a lower score. Therefore, equation Eq: 02 was used for this purpose.

$$x = 10 - \frac{Xa}{Xa+Xb} \times 10 \quad \text{(Eq: 02)}$$

Evaluation of overall performance through linear equation

Finally, the materials will be evaluated as a whole by developing a linear equation (Eq: 03) which uses the weightings derived from the AHP tools and normalized mean scores of each material. The equation is as follows.

$$y = m_e x_e + m_p x_p + m_d x_d + m_m x_m \quad \text{(Eq: 03)}$$

y	-	Overall score of the material
m_e	-	Weighted factor for embodied energy
x_e	-	Mean score of the material on embodied energy
m_p	-	Weighted factor for price
x_p	-	Mean score of the material on price
m_d	-	Weighted factor for durability
x_d	-	Mean score of the material on durability
m_m	-	Weighted factor for maintainability
x_m	-	Mean score of the material on maintainability

The following AHP approach was deliberated in order to prioritize the lists of the parameters.

1. Carrying out Pair wise comparisons among the parameters of
   - Embodied energy
   - Prices of Materials
   - Durability of Materials
   - Maintainability of Materials
2. Development of Pair wise comparison matrices
3. Development of Normalised weight matrices
4. Working out of Consistency calculations

4. DATA ANALYSIS AND FINDINGS

4.1. EVALUATION OF IMPORTANCE INDICES

4.1.1. DEVELOPMENT OF PAIR WISE COMPARISONS MATRIX

Different respondents had provided their judgments as pair wise comparisons in the questionnaires and a "Resultant" set of judgments attributable to judgment of all respondents had to be developed to make them usable in pair wise comparison matrices. In order to develop such a resultant set of judgments, it was required to calculate the "Arithmetic Mean" of similar comparison pairs in all the Questionnaires.

Calculation of arithmetic mean had to be carried out in a logical manner since there were some anomalies among the judgments provided by respondents. Without considering this anomaly of importance within same comparison pair, if the arithmetic mean is calculated for the corresponding levels of importance, the result might not be adequately accurate. In order to prevent such erroneous results, the following procedure was adopted.

It has been considered that a factor A to be more important over the factor B in any comparison pair as a convention. And whenever a respondent has judged the reverse, the "Reciprocal" value of the corresponding level of importance has been considered for mean calculation. Such an arithmetic mean of judgments of a comparison pair will be identified as the "Rating" of the comparison pair.

The completed comparison matrix is shown in Table 3 Main parameters have been arranged in same order as "Row headings" and "Column headings" in the matrix. Rating of each comparison pair has been entered into the matrix. In the next instance, the sum of each column was calculated.

Table 3: Pair Wise Comparison Matrix of Main Parameters

Criteria	Embodied Energy	Prices	Durability	Maintainability
Embodied Energy	1.0000	1.0213	0.8248	0.6914
Prices	0.9791	1.0000	1.5562	1.9874
Durability	1.2124	0.6426	1.0000	1.0267
Maintainability	1.4463	0.5032	0.9740	1.0000
Column Total	**4.6379**	**3.1671**	**4.3550**	**4.7055**

4.1.2. DEVELOPMENT OF NORMALIZED COMPARISON MATRIX

Subsequently, by dividing each entry of a particular column of the matrix by the sum of the respective column, the "Normalised comparison matrix" has been developed. Getting normalisation completed, arithmetic means (Averages) of figures in each row were calculated consequently obtaining the "Principle Eigen vector" of the matrix. Hence the averages became "Eigen values" of the matrix. Eigen values considered as "Importance Indices" of respective parameters, based on which the prioritisation of them has been carried out. The completed normalised comparison matrix is shown in Table 4.

Table 4: Normalized Comparison Matrix

Criteria	Embodied Energy	Price	Durability	Maintainability	Importance Indices
Embodied Energy	0.2156	0.3225	0.1894	0.1469	**0.2186**
Price	0.2111	0.3158	0.3573	0.4224	**0.3266**
Durability	0.2614	0.2029	0.2296	0.2182	**0.2280**
Maintainability	0.3119	0.1589	0.2236	0.2125	**0.2267**
		Sum of relative weights			**1.0000**

4.1.3. CONSISTENCY CALCULATIONS FOR MATRICES

The consistency calculations have to be done to measure the consistency of judgments made by respondents with regard to main parameters. As described in the research methodology a questionnaire having a CR value more than 0.1 will hinder the expert evaluation as random, causing the questionnaire to be rejected. According to the Consistency calculations, the derived CR value was 0.40 which depicts that the expert survey can be accepted.

4.1.4. IMPORTANCE INDICES OF MAIN PARAMETERS

Based on the results of the analysis using AHP tools, following importance indices shown in Table 5 were derived for each parameter of this study. These weightings will be used for developing the framework at later stages of the analysis.

Table 5: Importance Indices of Main Parameters

Criteria	Importance Indices	Rank
Embodied Energy	**0.2186**	**4**
Price	**0.3266**	**1**
Durability	**0.2280**	**2**
Maintainability	**0.2267**	**3**

According to above table, price is the most important parameter among the identified parameters followed by durability and maintainability. Embodied energy is considered as the least important parameter. But the difference between the indices among the factors of Embodied energy, Durability and maintainability is marginal. In the other hand, parameter of price has achieved the top position by a greater margin.

4.2. MATERIAL PERFORMANCE ON MAIN PARAMETERS

Figure 1 represents the normalized values derived from the scores of the questionnaire survey. Normalization was done as described in research methodology chapter using equation Eq: 01 and equation Eq: 02.

One of key points of this analysis is that, the research doesn't try to find the best material among the above list of materials. Rather, it prefers to identify the best material for each element among the above list. Based on the data from the above table, each material has performed differently on each parameter. Therefore, it would be beneficial to identify the performance of materials on each parameter individually before combining the results.

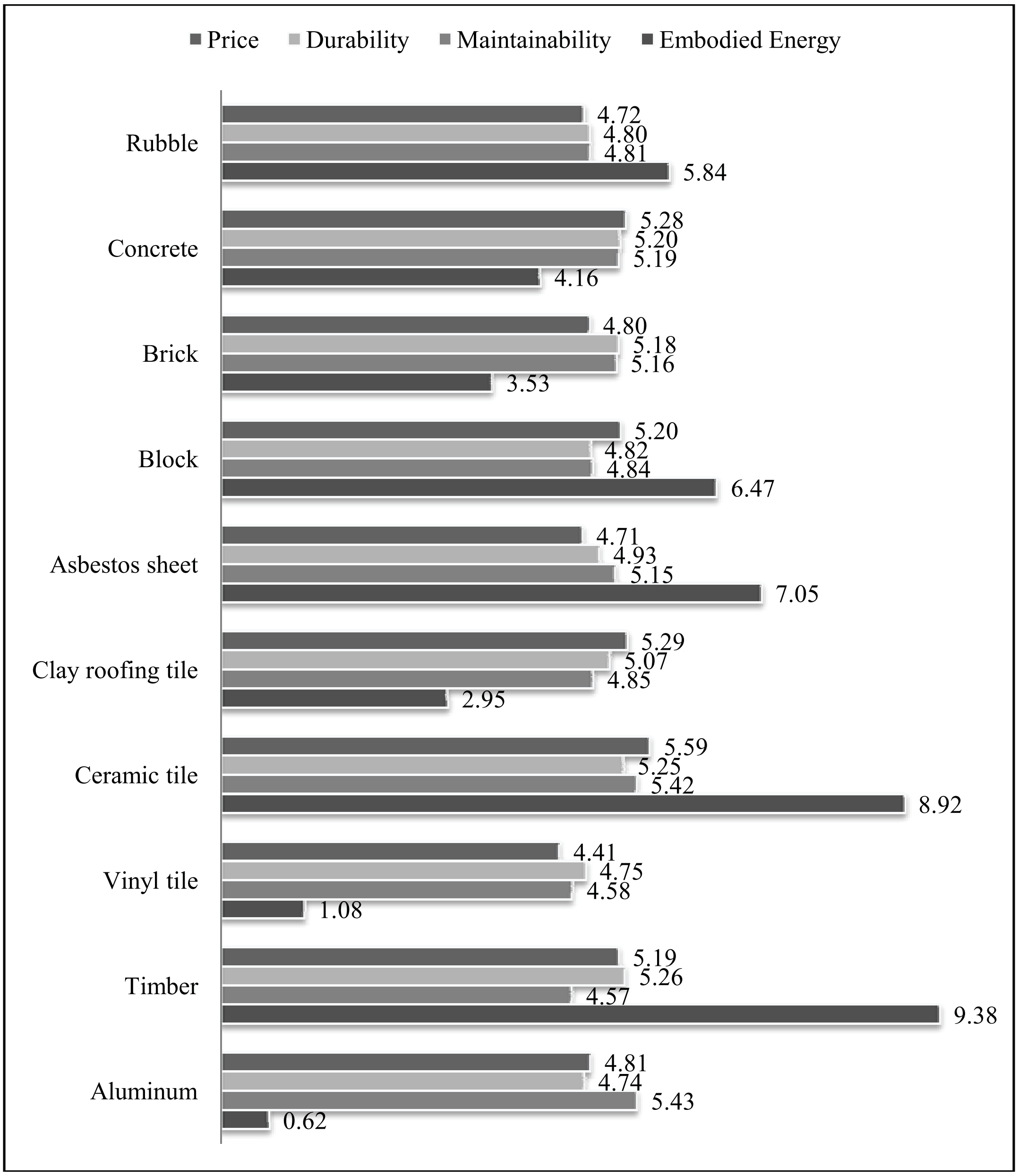

Figure 1: Normalized Mean Values of Material Performance on Main Parameters

4.2.1. EVALUATION ON INDIVIDUAL PARAMETERS

Figure 2 shows the performance of each material with regard to the parameter of embodied energy. Based on these results, the key point to be indentified is how certain materials of the same element have performed in diverse manner. These results are based on the findings from the literature review and not from the expert survey.

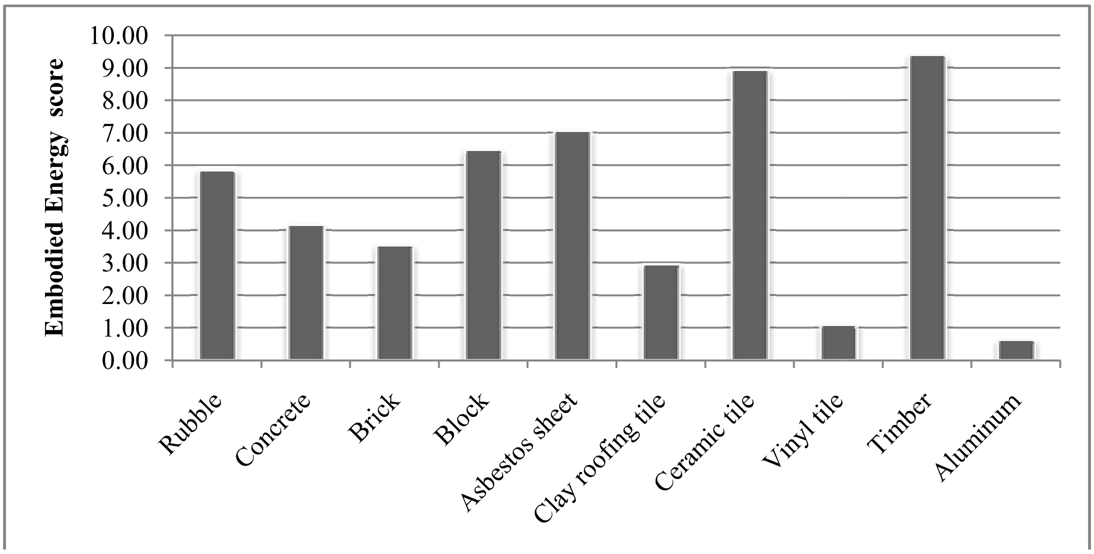

Figure 2: Performance of Materials Based on Embodied Energy

Vinyl tiles require large amount of energy for transportation while aluminium requires energy for extraction and preparation which increase the embodied energy of these materials compared to other material for the same element. These in terms have given them low score for the parameter of embodied energy. Timber has performed well in this regard as it has a very low embodied energy figure due to its ability to be dispose as firewood releasing energy. This has lead to timber achieving the highest score in this parameter.

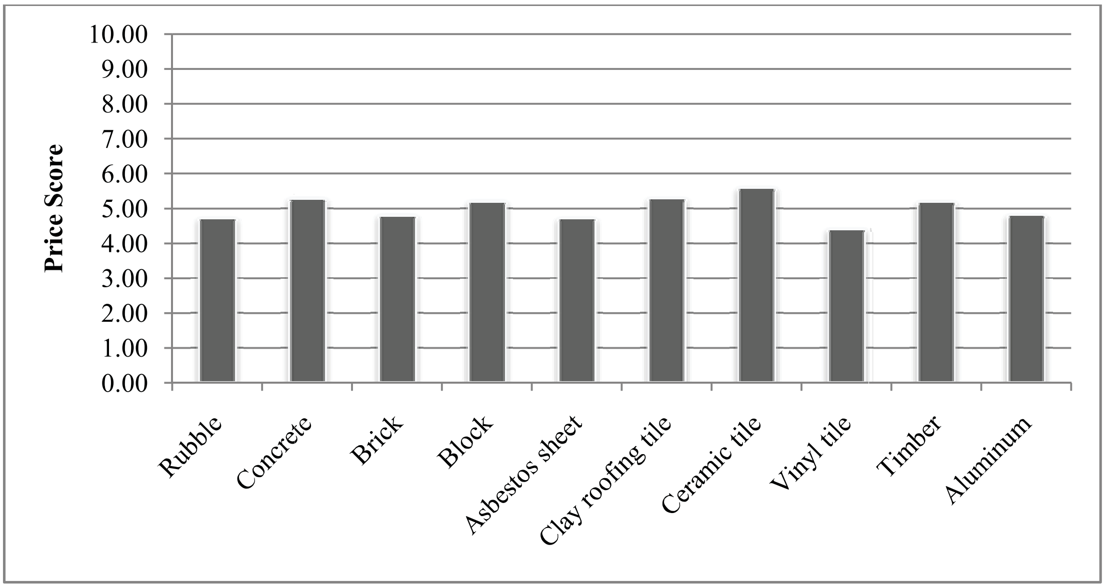

Figure 3: Performance of Materials Based on Price

According to Figure 3, all material has performed reasonably in the parameter of price compared to the alternative material of the element. Same can be said for durability and maintainability parameters by referring to Figure 4 and Figure 5.

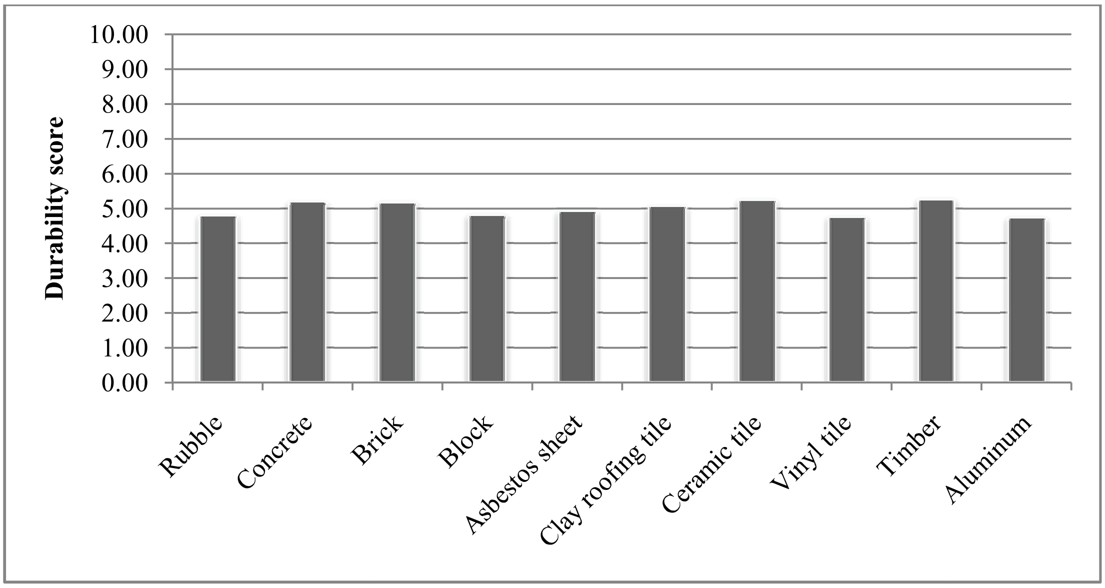

Figure 4: Performance of Materials Based on Durability

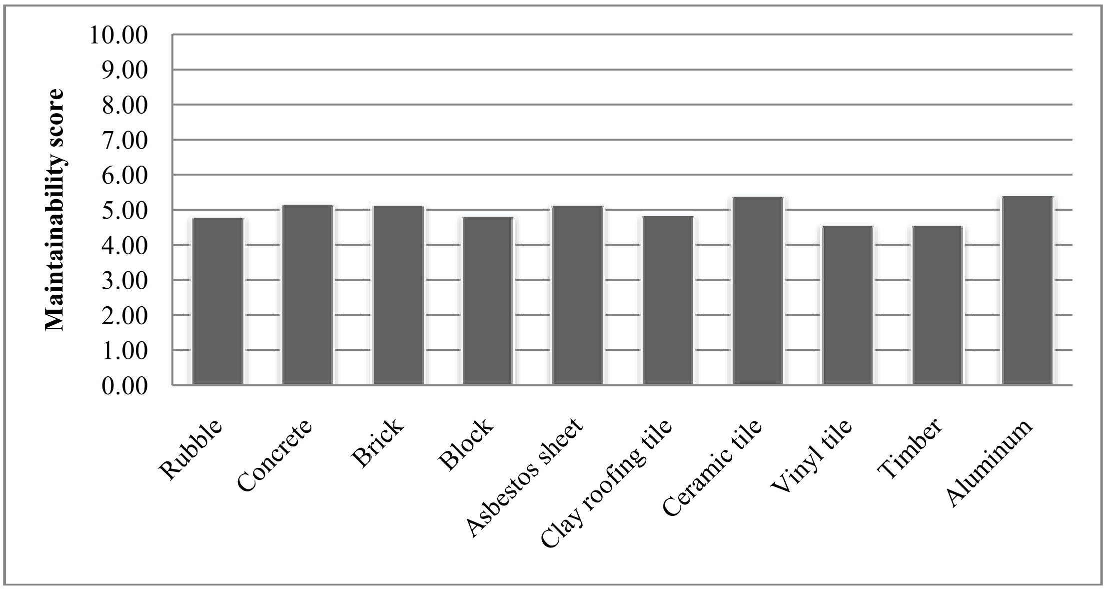

Figure 5: Performance of Materials Based on Maintainability

4.2.2. Embodied Energy vs. Other Parameters

Ignoring the importance indices derived from the AHP analysis tools; this research mainly focuses on the embodied energy parameter of materials. Therefore, it would be ideal to analyze how each material had performed on other parameters alongside embodied energy parameter.

In order to facilitate this, a scatter diagram was employed. Embodied energy of materials was considered in 'x' axis and other corresponding parameter in 'y' axis. Thereafter, the materials were placed in the diagram. The materials which perform best on both parameters can be found in the top right corner, while the materials underperforming were found in the bottom left corner of the diagram. This simplified the process of identifying the materials performance with regard to multiple parameters.

Based on the comparison among Embodied energy and price given in Figure 6, ceramic tile is the material which has performed best on both aspects compared to its counterpart. Even though aluminium for doors and windows has performed weakest in embodied energy, it has a reasonable score in the parameter of price. Vinyl tile has performed the weakest in price parameter and is among the worst performed materials in embodied energy parameter. Therefore, Vinyl tile can be identified as the least performed material considering both the parameters.

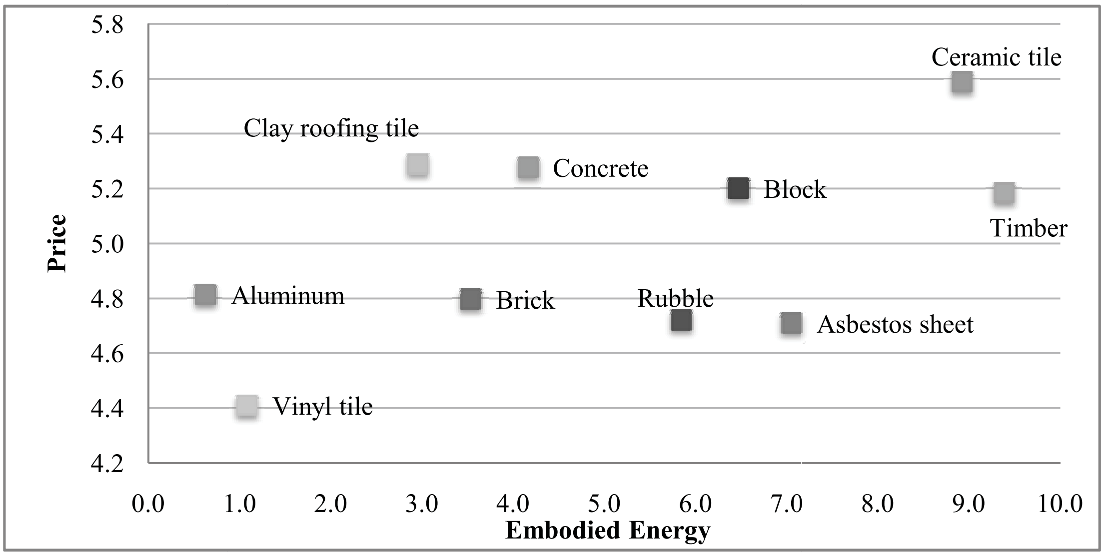

Figure 6: Material Performance Considering Embodied Energy vs. Price

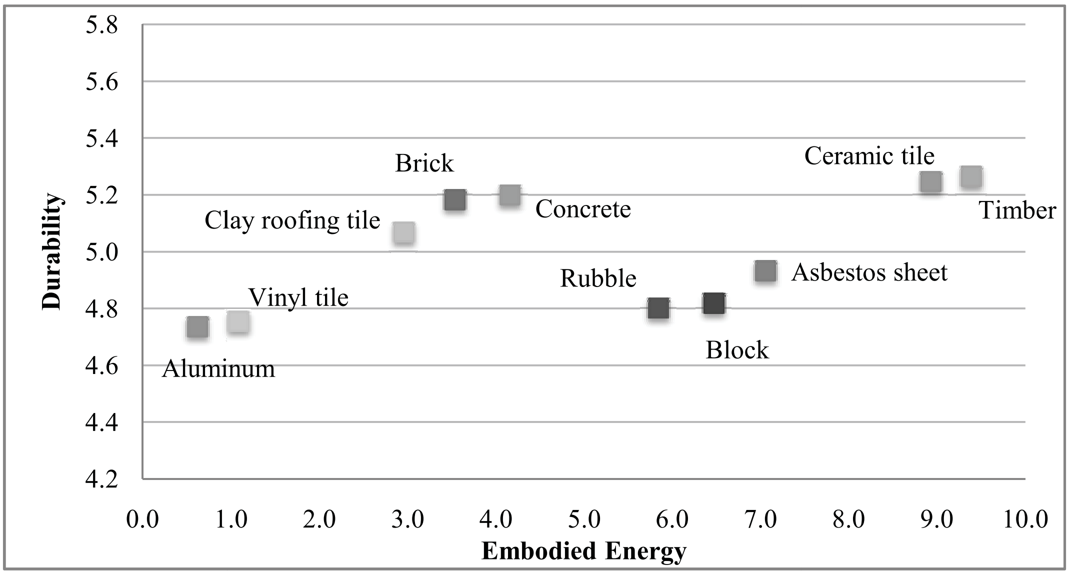

Figure 7: Material Performance Considering Embodied Energy vs. Durability

Figure 7 considers the parameters of embodied energy alongside durability. According the placement of materials in the diagram, Ceramic tile and timber doors and windows can be considered as the best performance while their counterparts are the materials which have the weakest performance. All other materials have scattered in between these elements.

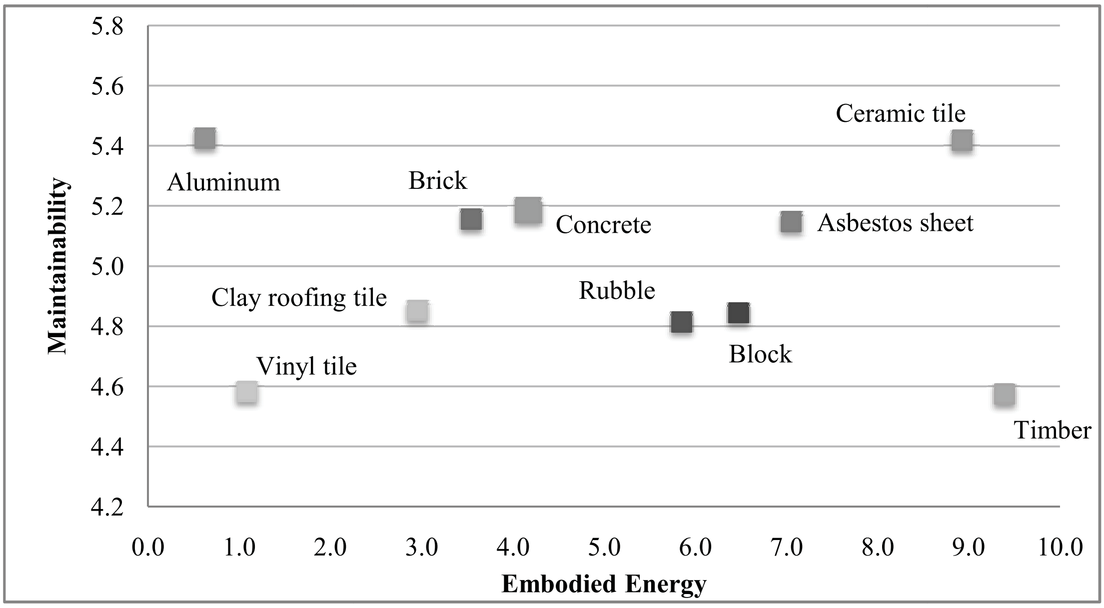

Figure 8: Material Performance Considering Embodied Energy vs. Maintainability

Ceramic tiles again have outperformed its counterpart vinyl tile by a huge margin when embodied energy figures were compared along with the figures of maintainability as shown in Figure 8. All other material combinations are reasonably spread in the diagram.

4.2.3. EVALUATION OF OVERALL PERFORMANCE OF MATERIAL

As discussed in the research methodology, a linear equation (Eq. 03) was developed in order to evaluate each material with all the parameters considered. All the necessary inputs of importance weightings and normalized mean scores have been calculated and based on those calculated figures, Figure 9 is a graphical representation of the results derived for each material.

Figure 10 shows the overall score received by each material alongside the scores received for main parameters. This information helps to identify how the each parameter performances have affected the overall score. It is graphical representation of the effect of importance weightings derived from AHP tools.

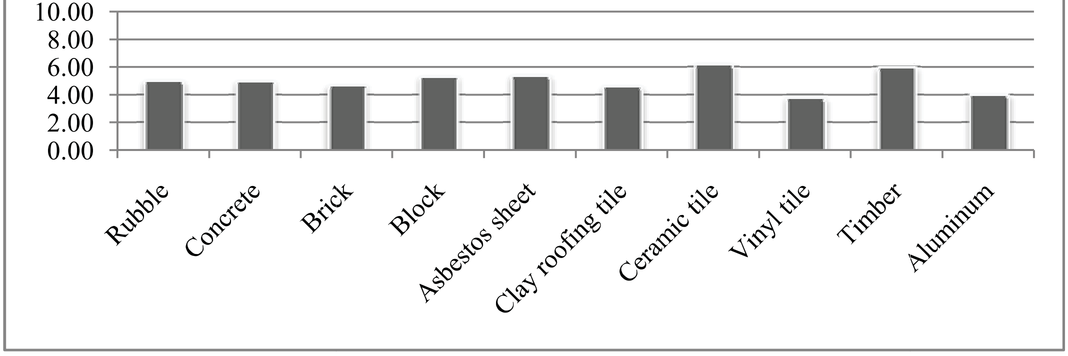

Figure 9: Overall Performance of Materials

For most of the materials, the overall score has vastly deviated from the embodied energy parameter score. This is due to embodied energy having the lowest of importance from the AHP weightings. Other considerable fact is the minimal deviation between the price parameter and overall score. This can be clarified as due to the high value weightings received by price parameter in the AHP weightings.

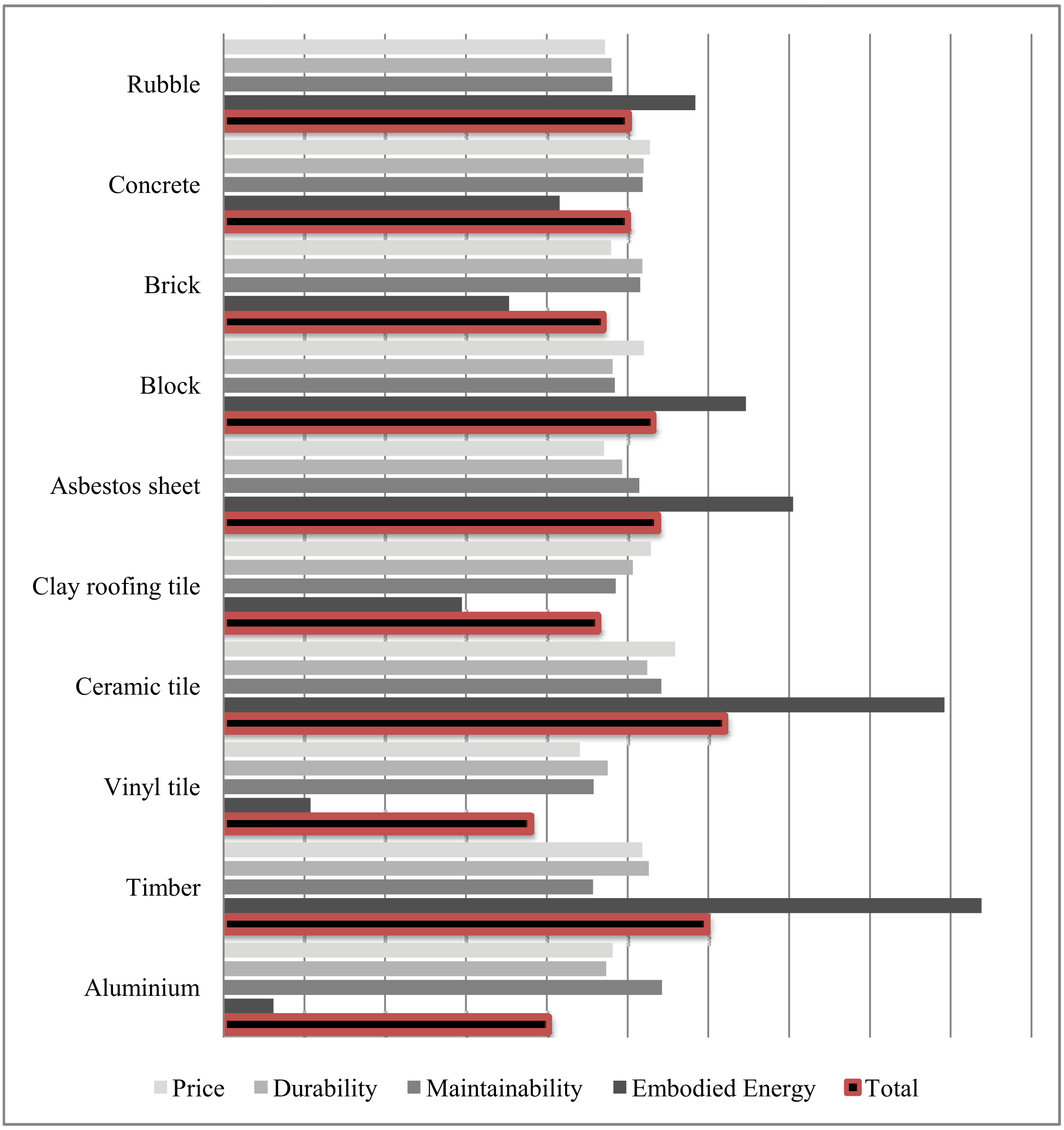

Figure 10: Comparison of Overall Performance with Parameter Performance of Materials

4.3. *DEVELOPMENT OF FRAMEWORK FOR SELECTION OF MATERIAL*

In order to achieve the aim, different combinations of the selected materials for each building element had to be drawn up. Therefore, four combinations of each of these materials were analyzed with each other in terms of their performance in each individual parameter and on overall performance. Thus, results from previous sections are used in this evaluation process.

Based on the materials' overall performance, two combinations of material types were selected. Type 1 combination consists of the materials which had the highest overall score for each element while Type 2 combinations is the opposite of Type 1 and consists of materials with the lowest overall score for their respective element. Type 3 combination consists of a random selection of materials for each element whereas Type 4 combination consists of the counterparts of the Type 3 materials. Materials applicable for each type of combinations are listed in Table 6.

Each combination was evaluated for performance on the main parameters with the use of the normalized mean scores derived from the questionnaire survey. Thereafter, overall performances of the combinations were calculated using the importance weightings calculated using AHP tools.

Table 6 - Material Combinations for the Framework

	Type 1	**Type 2**	**Type 3**	**Type 4**
Foundation	Rubble	Concrete	Rubble	Concrete
Wall	Block	Brick	Brick	Block
Roof	Asbestos sheet	Clay roofing tile	Clay tile	Asbestos sheet
Floor finishes	Ceramic tile	Vinyl tile	Ceramic tile	Vinyl tile
Doors & windows	Timber	Aluminium	Timber	Aluminium

Figure 10 is the graphical representation of performance of each configuration of materials whereas of same data.

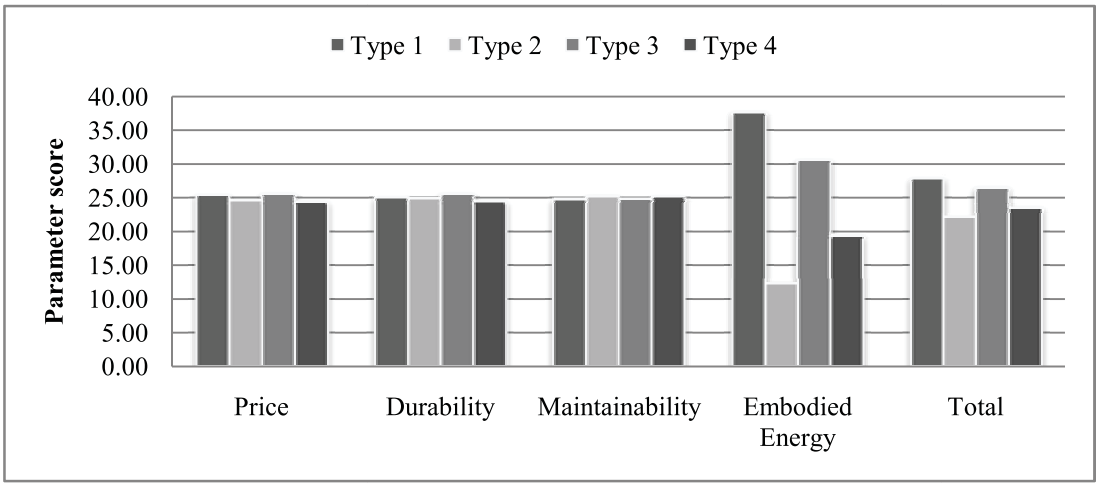

Figure 10: Performance of Material Combinations

Based on the facts it can be understood that performance of all combinations are somewhat similar on parameters of price, durability and maintainability. But in the case of embodied energy, Type 1 has achieved a very high score, whereas type 2 has performed very weak. This was an expected result as Type 1 and type 2 combinations are the highest performed and lowest performed combinations of materials. But the scale at which they have differed is hefty.

When considering the overall score of each combination, the results are obvious about how each combination have performed given that in all other parameters except embodied energy, all the combinations have performed at the same level with minor variations. Therefore, it can be determined that results of the embodied energy have twisted the results to a certain extent. But it has required embodied energy to deviate by a large amount in order to diverge the overall results by a reasonable amount. The low importance weighting received for embodied energy parameter can be identified as the effect for this phenomenon.

Table 7 shows the rankings of each combination on overall performance and individual parameters parameter performance.

Table 7 - Ranking of Material Combinations Based on Performance

	Price	**Durability**	**Maintainability**	**Embodied Energy**	**Total**
Type 1	2	2	4	1	**1**
Type 2	3	3	1	4	**4**
Type 3	1	1	3	2	**2**
Type 4	4	4	2	3	**3**

Rankings in parameters of price, durability and maintainability are different from the overall ranking of material combinations while embodied energy ranking is the same. Therefore it can be identified that even though embodied energy score in importance weightings is low, it still has the some momentum to change the overall rankings of the framework.

It should be predicted at the beginning that Type 1 material combination will supersede all other combinations while Type 2 will become last in the ranking. All other possible combinations of material will eventually have their overall score value between the values derived by Type 1 and Type 2. This is due to the selection of all highest overall scoring materials for Type 1 combination and lowest scoring materials for Type 2 combination.

Above mentioned incident can also be observed by referring to Figure 11. The radar diagram shows how each selected materials configuration has performed in terms of selected parameters. Therefore, all possible combination of materials for the elements will eventually be place between the Type 1 and Type 2 values.

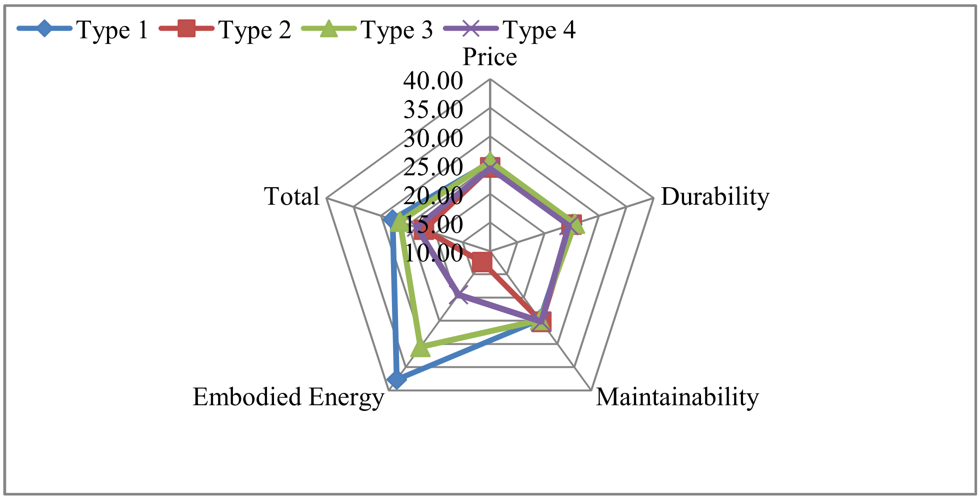

Figure 11: Radar Diagram for Performance of Material Combinations

5. SUMMARY

Many developed countries have made substantial progress in the green building movement establishing standards and benchmarking green building practices. All green rating systems evaluate a wide range of factors to ensure that a selected construction can be accredited as environmentally sustainable. Out of the several factors considered, materials selection can be considered as a high priority aspect as construction materials uses resources of the country. Almost all resources available to mankind are scarce by default and needs to conserve for future generations. Therefore assessment of environmental burdens associated with different construction materials used for buildings is necessary in order for decision-makers to select environmentally benign materials. Hence, this research focused on identifying the cost significant and mostly used building materials for construction in Sri Lanka and to develop a framework for selection of materials based on embodied energy and other identified main parameters.

The study was carried out based on figures retrieved from literature survey as well as on the perceptions of professionals involved in construction through questionnaire survey. The study categorized the identified significant materials based on five major elements with two materials per each and evaluated their performance based on the parameters of embodied energy, price, durability and maintainability. During the questionnaire survey it was identified that most of the professionals were not aware of the concept of embodied energy. But when clued-up, they have considered it to be a relatively important factor for materials selection.

According to the view of professionals, most of the selected materials of the same element have performed in similar manner on the selected parameter. But in the case of vinyl tile for floors and aluminium for doors and windows the results for embodied energy has a significant difference with their counterparts. This has lead to the reduction in the overall score of these materials. Materials were also evaluated based on their performance in multiple parameters where price, durability and maintainability were compared with the main parameter of embodied energy. In all these evaluations, Aluminium doors and windows along with vinyl floor tiles have performed weak compared to their counterparts. Ceramic tiles and timber doors and windows have outperformed all other materials in every multiple comparisons of parameters.

Based on those findings, the development of framework was done by identifying four combinations of the selected materials for analysis. One of these combinations consisted of materials with the highest overall score for each element while another with the lowest. The analysis showed that even though the performance of each combination varied according to the parameters, the overall score of each combination varied in between the scores of highest scored material combination (Type 1) and lowest scored material combination (Type 2).

During this development process, it was also identified that, even though embodied energy parameter ranked last in the importance weightings, the parameter is of acceptable significance. This is clearly depicted when analysing the scores derived for each material configuration (Table 4.6) in framework development process. In Table 4.7, Embodied energy is the only parameter which has ranked the combinations similar to that of the overall rankings. All other parameters, including the top ranked price parameter also had ranked materials differently to that of the overall ranking. Thus, it can be concluded that embodied energy has a very high implication to the overall material selection process and should be given serious consideration.

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DEVELOPING A MAINTENANCE STRATEGY PLAN TO IMPROVE ENERGY EFFICIENCY OF HVAC SYSTEM

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ABSTRACT

In managing energy in buildings, a greater focus has been given to the HVAC system as it generally consumes more than 50% of total energy usage in buildings. Proper maintenance had been identified as a significant factor to improve energy efficiency of HVAC systems. For instance a proper maintenance plan can save 5% - 20% of energy bills without a significant capital investment. Thus, the research aims to develop a maintenance strategic plan to improve energy efficiency of HVAC systems. Survey technique was adapted to collect data on HVAC system failures, impact of failures, frequency of each failure, significance of causes for failures and HVAC Maintenance requirements to ensure efficiency. A statistical analysis was carried out to develop a maintenance strategy plan. Maintenance strategic plan is proposed by using the preventive and predictive maintenance strategy. This proposed plan may be useful for building managers to manage energy by adopting efficient maintenance strategies.

Keywords: *Energy Efficiency; HVAC System; Maintenance; Predictive Maintenance; Preventive Maintenance.*

1. BACKGROUND

HVAC stands for heating, ventilation and air conditioning and refers to the equipment, distribution network and terminals used either collectively or individually to provide fresh filtered air, heating, cooling and humidity control in a building (ASHRAE, 2009). Moreover, Zhang (2005) has mentioned that the HVAC Systems are mechanical systems providing artificial environment for either operational requirement or health and comfort of the occupants. According to Johnson (1995) the main goals of HVAC system is to maintain the comfort and health of occupants or the supplying of a set of environmental conditions for a process or product in a conditioned space.

The choice of HVAC system depends on initial cost, energy cost, maintenance effort and cost, coordination with other trades, spatial requirement, acoustics, flexibility, architectural aesthetics, and many other issues (California energy commission, 2005). HVAC system is the largest energy consumer in a building thus potentially an area where large energy savings may be realized. According to Liddament and Orme (1998), HVAC system approximately consumes more than 50% of energy from the total building energy usage (Figure 1).

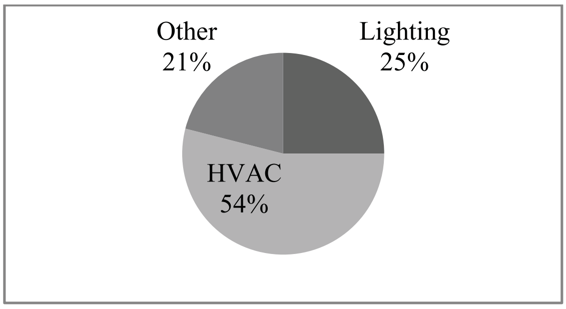

Figure 1: Breakdown of the Total Building Electrical Energy Consumption (Source: Liddament and Orme, 1998)

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US Department of Energy (2010) has been estimated that operation and maintenance programs targeting energy efficiency can save 5% to 20% on energy bills without a significant capital investment. Moreover, office of the legislative auditor (2010) has mentioned that training maintenance workers in preventive maintenance, improved the efficiency of HVAC operations saves an estimated 6% to 19% of their total annual energy bills. Adequate cleaning of the condenser or evaporator coils could provide the same amount of cooling with 30% to 40% percent less energy consumption than inadequate cleaning (Office of the legislative auditor, 2010). According to western area power administration (2006) an improperly maintained cooling tower will produce warmer cooling water, resulting in a condenser temperature 5 to 10 degrees F higher than a properly maintained cooling tower. This reduces the efficiency of the chiller, wastes energy, and increases cost. The chiller will consume 2.5 to 3.5 percent more energy for each degree increase in the condenser temperature. Proper maintenance is necessary to achieve optimal energy performance, while energy performance data is needed for effective maintenance management. When the tensions between energy performance and maintenance practices are balanced, buildings operate efficiently as shown in the Figure 2.

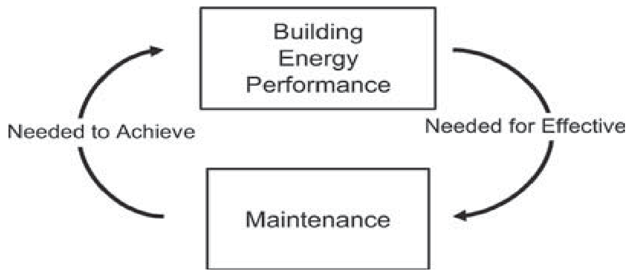


Figure 2: Link between Energy Performance and Maintenance
Source: (Lewis and Elmualim, 2010)

Western area power administration (2012) identified most common failures of HVAC system which affects the functionality such as leak of refrigerant, compressor failures, fan motor failures, electrical failures, fan bets failure, scale deposit, valve failure, drain pump leak and pump failure. Chandrashekaran and Gopalakrishnam (1999 cited Abramson and Magee 2008) has explained that preventive maintenance and predictive maintenance can be used to improve HVAC failure checkpoints, such as scale, corrosion, fouling of heat transfer surfaces, misalignment, improper lubrication, lack of calibration in control systems, equipment operating unnecessarily, excessive parasitic losses, leaks, and failure to utilize free energy sources. According to Chandrashekaran and Gopalakrishnam by using this can be achieved 6 % -19 % potential energy savings in HVAC system. Cleaning, replacing damaged items, visual inspection, chemical treatment and checking water in/ out temperature are some of the preventive maintenance and predictive maintenance activities which need to be carried out in regular basis (Schoen, 2003).

Robert and Rosaler (1997), Lofsten (1999), Deshmukh and Garg (2006) and Luxhoj *et al*. (1997) mentioned that preventive maintenance is time based maintenance which a series of tasks performed at a frequency dictated by the passage of time. Predictive maintenance is the extrapolation of graphic trends of measured physical readings against known engineering limits for the purpose of detecting, analyzing, and correcting equipment problems before failure (Raouf and Ben-Daya, 1995; Tsang, 2002). Jabar and Perkasa (2003) have mentioned that the proactive maintenance strategy is also designed to extend the useful age of the equipment to reach the wear-out stage by adaptation a high mastery level of operating precision. According to Horner (1997 cited David and Arthur 1989) has mention that corrective maintenance tasks often take places in an *ad hoc* manner in response to breakdowns or user requests. It is required to use a combination of all these maintenance strategies to obtain the optimal performance of a system.

2. RESEARCH METHODOLOGY

Surveys are normally used where the views or opinions of many need to be evaluated in order to achieve a conclusion. Therefore, survey research has been selected as the most suitable research approach. A literature survey was undertaken, in order to identify practising maintenance strategies, the failures arise in the HVAC system and the maintenance activities could be carried out to avoid these failures. These finding were further validated using a pilot survey where an expert was involved. In order to collect the data from the industry a structured questionnaire survey was developed using the identified practising maintenance strategies, HVAC failures and maintenance activities. A statistical analysis was carried out to analyse collected data; mainly t-test was carried out using SPSS software with 95% confidence interval. Preventive and predictive maintenance activities were proposed for chiller maintenance based on the literature survey.

3. RESEARCH FINDINGS

3.1. PRACTICING MAINTENANCE STRATEGIES

Survey results showed that *preventive maintenance* strategy was the most widely practicing method in most of the organizations. Furthermore, combination maintenance strategies are also popular among organizations which information is presented in Figure 3.

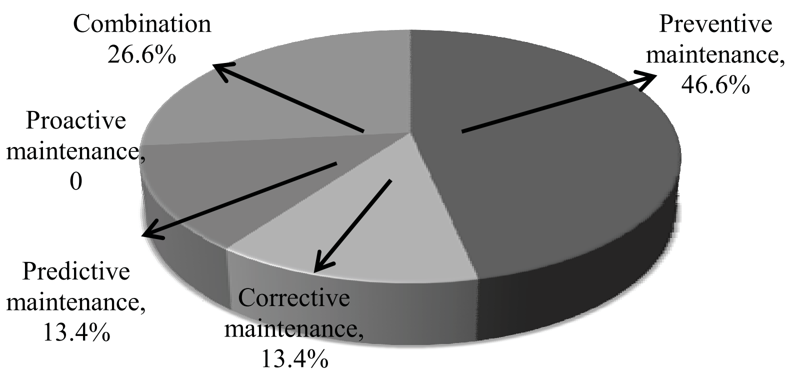


Figure 3: Usage of Maintenance Strategies

3.2. HVAC MAINTENANCE REQUIREMENTS

Maintenance requirements for HVAC system were analyzed according to the three common systems available as, Central A/C system, Split type A/C and package A/C. The following section discusses their maintenance requirements in detailed.

3.2.1. CENTRAL A/C SYSTEM MAINTENANCE

Maintenance requirements for Central A/C system were analysed according to the three main components including (1) chiller, (2) cooling tower and (3) pumps. Maintenance activities for each component were proposed and practitioners were asked to mark the importance of each proposed maintenance activity on a given scale of one to five representing very high, high, medium, low and very low respectively. T-value and significance of each maintenance activity was calculated and ranked them based on the t-values to identify most important maintenance activities. The following section discusses their maintenance requirements in detail.

Chiller

Table 3: Maintenance Requirements for Chiller

Factors		95% Confidence Interval of the Difference			
		t- Value	P Value	Mean Rating	R
1	Inspect for water leaks	-5.635	.000	-.933	1
2	Checking all oil levels and pressures	-6.528	.000	-1.100	2
3	Check Chilled water in/ out temperature	-3.516	.001	-.767	3
4	Checking all electrical starters, contactors and relays	-3.515	.001	-.733	4
5	Inspect purge unit operation	-3.440	.002	-.667	5
6	Check for unusual noise and vibration	-3.194	.003	-.733	6
7	Prompt power consumption	-2.850	.008	-.633	7
8	Assess proper water flow in evaporator and condenser	-2.628	.014	-.500	8
9	Check for chill fouling in Chilled water/ Condenser Water	-2.523	.017	-.600	9
10	Conduct leak testing on all compressor fittings, oil pump joints and fittings , and relief valves	-2.408	.023	-.500	10
11	Prompt cooling capacity	-2.347	.026	-.500	11
12	Checking compressor operating pressures	-2.333	.027	-.533	12
13	Check Condenser Water in/ out temperature	-2.186	.037	-.500	13
14	Inspect water treatment process	-2.151	.040	-.533	14
15	Check Ph of condenser water	-1.000	.326	-.207	15
16	Check Ph of chilled water	-.817	.420	-.167	16
17	Eddy current testing for chiller tubes	-.701	.489	-.133	17

T-test analysis showed that fourteen maintenance activities have a p-value less than 0.05 and others have p-values more than 0.05 (Table 3). Therefore, activities which have p-value less than 0.05 can be considered as most significant activities which need to be carryout in a regular basis. It is important to inspect the water leaks of the chiller shell and tube heat exchanger. The tube can fail due to corrosion and the resulting leak would be catastrophic, resulting in rapid failure and expensive repair and replacement. To predict and prevent such failure, eddy current analysis is used to detect the condition of the heat exchanger surface.

The failure of an oil pump is another critical faulty in HVAC system. All compressors which are used oil pumps should have an oil failure control system and proper working order. The condensing pressure is the amount of pressure required within the system to take the heat out of the water. The condensing pressure can be measured with the set of pressure gauges on the pressure taps at the inlet and outlets of the condenser itself. If the two are more than three degrees different, need to check the purge system operation for leaks. Maintain the makeup water supply pressure between 15psig and 50 psig to ensure proper valve shut off and to avoid failures. If the supply pressure is higher than 50 psig, install a pressure reducing valve. The function of any float valve is allow a reasonable discharge into a cistern and be capable of closing off against maximum pipeline pressure. Frequent reasons for failures in float valve are Dirt on valve seat, Valve face is worn, the float / lever mechanism has insufficient operating force to close against the shut off pressure. In order to avoid these failures must do the clean and replacement accurately.

Difference between chill water in out temperature should be maintained at the acceptable level. If not it will cause inefficiency in both chiller and the cooling tower. Temperature sensors and motorised valves should be placed appropriately to avoid unnecessary cooling by the chiller. Maintaining all electrical starters, contactors and relays is essential to enhance the automatic operation of the equipment. If not equipment may operate without any usage which will cause energy inefficiency.

Cooling Tower

According to t-test, there were six important maintenance activities for cooling tower maintenance. Among the proposed fourteen activities, eight are not consider as important and not significantly practice in the industry. Table 4 shows more details on calculations and ranking of each activity.

Table 4: Maintenance Requirements for Cooling Tower

Factors		95% Confidence Interval of the Difference			
		T-Value	Sig:	Mean Rating	Rank
1	Cooling tower entering/leaving temperature	-3.45	.002	-.793	1
2	Check the condition and lubricant the bearing, replace if necessary	-3.46	.002	-.690	2
3	Use high pressure water pump and clean entire CT, start from top to bottom	-3.01	.005	-.552	3
4	Fouling - check for algae build up	-2.73	.011	-.483	4
5	Check the condition of the fan motor through temperature or vibration analysis and compare to baseline values	-2.65	.013	-.552	5
6	Cooling tower fan motor current (Amp)	-2.24	.033	-.517	6
7	Sump free of debris / no algae	-2.04	.051	-.448	7
8	Check for excessive vibration in motors, fans, and pumps	-1.84	.076	-.414	8
9	Check motor terminal and tight them	-1.75	.091	-.448	9
10	Check V-belts and pullies of the motor and align them properly	-1.39	.174	-.310	10
11	Open CT in and out valves, put on condenser pumps and CT fan and balance the system	-1.21	.234	-.276	11
12	Chemical treatment	-.98	.336	-.241	12
13	Check make up float valve operation and adjust if necessary	-.86	.396	-.207	13
14	Close the drain valve and open make up water valve	-.70	.489	-.138	14

Out of fourteen proposed maintenance activities, only six were identified as significant maintenance requirements in the cooling tower. The most consideration in cooling tower should be given to the entering and leaving temperature of the cooling tower water. Cooling tower has the ability to decrease about 5 ^{O}C from the entering temperature, thus it vary with the climatic deviations.

Bearing speed plays a vital part in lubrication frequency. Most of the blowers are run at the much higher speed further higher speed requires more frequent lubrication. According to the opinion of the experts standard field practice is most commercial service companies perform maintenance in lubricating bearings 4 times a year.

Cleaning of cooling tower surface and fins has a direct relationship with its efficiency because growth algae disturb the heat transmission. Therefore, cooling tower should be regularly cleaned using high pressure water. Condition of the cooling tower fan has a notable relationship with the efficiency of heat transmission of the water. Usage of energy and rotation speed of the fan needs to match with the functional requirement.

Pumps

According to survey analysis there are eight important maintenance activities for pump maintenance (Table 5). Among the proposed fourteen activities, six are not consider as important and not significantly practice in the industry.

Table 5: Maintenance requirements for Pumps

Factors		95% Confidence Interval of the Difference			
		t- Value	**Significance**	**Mean Rating**	**Rank**
1	Lubricate bearing	-3.80	.001	-.767	1
2	Check and replace grease motor and pump bearing	-3.75	.001	-.700	2
3	Visual Inspection	-3.07	.005	-.633	3
4	Vibration Monitoring/Analysis	-2.57	.016	-.533	4
5	Water pump in/ out pressure	-2.52	.017	-.600	5
6	Test run and check for abnormal vibration and noise	-2.47	.019	-.600	6
7	Wear Particle Analysis	-2.44	.021	-.533	7
8	Check drain lines	-2.31	.028	-.467	8
9	Check the condition of valve and fittings	-1.54	.134	-.333	9
10	Lubricant, Fuel Analysis	-1.50	.143	-.333	10
11	Check tension of belts and adjust pulley over heating	-1.45	.155	-.367	11
12	Pump current consumption (Amp)	-1.41	.167	-.400	12
13	Bearing, Temperature/Analysis	-1.35	.186	-.333	13
14	Ultrasonic Noise Detection	-.92	.362	-.167	14

In central air conditioning system, condenser water pumps and the chill water pumps play a major role. Lubrication of bearing has identified as the most necessary maintenance activity. The impeller and the shaft of the pump move with the use of bearings, thus lubrication is required to smooth rotation and to avoid wear and tear. Vibration analysis and noise analysis details can be used to forecast possible failures of a pump. When rotating equipment is installed, an initial vibration analysis provides a baseline for future comparative reviews. There are number of numerous reasons for increased vibrations, such as worn shaft, worn bearing, chipped impeller, failed motor insulation, lost balance weight and dirt on the fan blades.

According to the practitioners view, practising daily visual inspections aiming at detecting signs of possible fault, for example, oil or coolant leaks, structural cracks, or cutting-edge wear is important. This also includes the mechanical adjusting and tune-up of equipment and the detection and correction of small problems before they become major problems. Items requiring attention should be reported. As well as equipment failures occur due to wear outs and random causes. While random failures cannot be eliminated totally, wear out failures can be eliminated by preventive maintenance operations.

3.2.2. Split Type A/C System Maintenance

T-test results emphasised that five maintenance activities for split type A/C maintenance were important (Table 6). Among the proposed ten activities, five are not consider as important and not significantly practice in the industry.

Table 6: Maintenance requirements for Split A/C system

	Factors	95% Confidence Interval of the Difference			
		t- Value	Sig:	Mean Rating	Rank
1	Cleanliness of filters	-3.62	.003	-1.00	1
2	Current amperage	-3.16	.007	-.66	2
3	Check and clean evaporator fan motor and lubricating motor bearing and moving parts	-2.86	.013	-.80	3
4	Check corrosion of base plate and cover of condenser and paint using anticorrosion paints if necessary	-2.46	.027	-.66	4
5	Clean condenser blower and lubricating	-1.52	.150	-.53	5
6	Pressure washing of condenser coil and chemicals if necessary	-1.41	.178	-.53	6
7	Visual inspection for proper refrigerant charge- (liquid line-Warm) , (Suction line- Sweaty)	-.96	.353	-.33	7
8	Clean air filters and inner grill cover	-.96	.353	-.33	8
9	Check blower fan and make necessary adjustments	-.61	.550	-.20	9

If air filters are not clean it affects the distribution of air by the split A/C system. Air filters need to be cleaned with use of a vacuum cleaner or they can be washed. Air filters should be replaced if necessary. By replacing filters often, can remain pure air and healthy against bacteria that can be harmful to lungs. Fresh replacements keep the HVAC system running correctly by extending its lifespan and reducing utility bills by keeping properly maintained. Should inspect filters at least once a monthly to see if need cleaning or replacement. If not conduct the maintenance routinely, the system will have to work extra hard, reducing performance and increasing cost.

When electric motors are subjected to voltages which below the nameplate rating, some of the characteristics will change slightly and others will change more dramatically. A basis point is to drive a fixed mechanical load connected to the shaft a motor must draw a fixed amount of power from the power line. The amount of power the motor draws is roughly related to the voltage current (amps). Thus, when voltage gets low the current must get higher to provide the same amount of power. The fact that current gets higher is not alarming unless it exceeds the nameplate current rating of the motor. When amps go above the nameplate rating it is safe to assume that the build-up of heat within the motor will become damaging if it is left unchecked. If a motor is lightly loaded and the voltage drops the current will increase in roughly the same proportion that the voltage decreases.

3.2.3. PACKAGE A/C SYSTEM

T-test identified two important maintenance activities for split type A/C maintenance (Table 7). Furnace filters not only screen out unwanted pollens and debris from HVAC systems, but also increase the system's productivity. Moreover cleaning and adjustment of the equipment can be reduced the down time and repair costs. As well as replacing of filters and belts cause to create a healthier indoor work environment and optimal running efficiency. In addition it is more important to keep the evaporator coil free of dust, dirt, and debris because these materials act as a layer of insulation and reduce the system's ability to cool the air that flows across the evaporator coil.

Table 7: Maintenance Requirements for Package A/C System

Factors		95% Confidence Interval of the Difference			
		t- value	Significance	Mean Rating	Rank
1	Clean air filters for accumulated dirt by a vacuum cleaner or washing in water/ replace air filters if necessary	-5.17	.000	-1.067	1
2	Clean evaporator blower and straight damaged fins using fin comb	-4.52	.000	-.933	2
4	Clean condenser inner tube by circulating a diluted acid and straight damaged fins using fin comb	-1.82	.089	-.467	3
3	Check evaporator fan for a loosed v belts and abnormal sounds	-1.04	.313	-.333	4

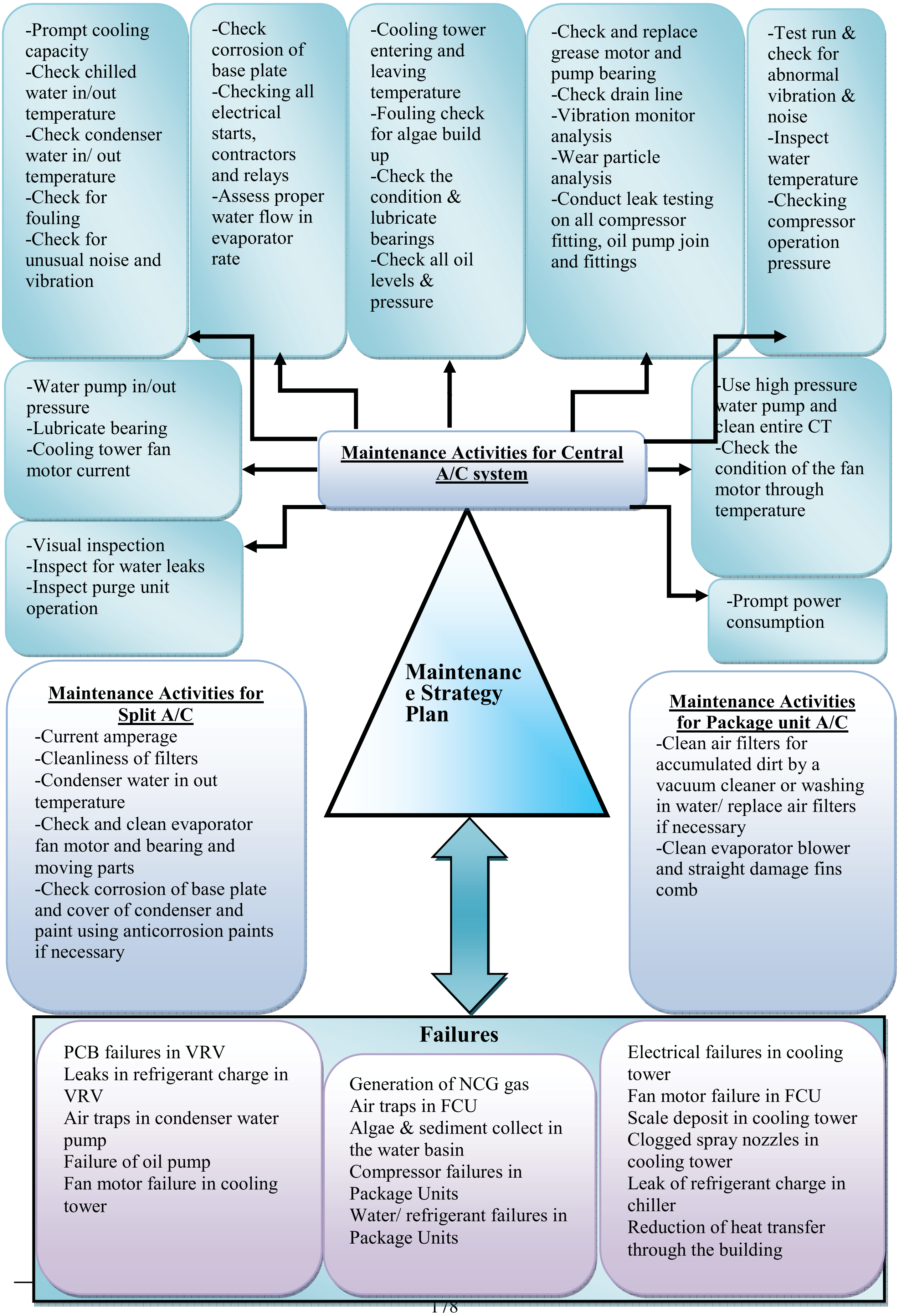
4. CONCLUSIONS

Properly managed maintenance strategic plan of HVAC system will be optimizing the building comfort level, providing less down time and repair costs, providing healthier indoor work environment and optimal running efficiency, maximizing energy cost while maintaining a comfortable work environment and equipment runs more efficiently as well as extends the life time of the equipment.

According to findings preventive maintenance strategy was practiced by most of the organisations. Among the proposed maintenance activities some were identified as significant for the operation of the system. Thus, findings emphasised list of preventive and predictive maintenance activities in order to optimise the energy efficiency of HVAC system.

Maintenance can be used to minimize the maintenance cost, premature failures of building components, cost of maintain testing equipment, sudden maintenance, requirements of staff training, impact for safety of the equipment (durability) and the health and safety requirements. Therefore, a maintenance strategy plan was developed considering preventive maintenance, predictive maintenance strategies. Maintenance plan shows the most important preventive and predictive maintenance activities for central A/C system, split A/C system and package A/C system. The proposed plan may be useful for building managers to manage energy by adopting efficient maintenance strategies.

3.3. *MAINTENANCE STRATEGY PLAN*



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DEVELOPMENT SUPPORTIVE NOVEL TRENDS AND PRACTICES FOR CONSTRUCTION SECTOR

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ABSTRACT

The rapid development of the technology paved the way towards the new trends and innovations in each and every industry. This is a universal truth which has no any exceptions to the construction industry which faces rapid changes frequently while being one of the major industries of a country that contribute to the living standard of the citizens and to the development of the country.

Sri Lanka being one of the countries with booming economies, it is inevitable to respond to the innovations in world construction industry and there are some important new trends to the development of the industry. Therefore, this research is carried out to address the research gap to identify the important new trends of the Sri Lankan construction industry.

In order to proceed with the research, quantitative research approach was adopted through a questionnaire survey with 90 respondents including clients, contractors and consultants 30 from each. Data were analyzed statistically and were ranked based on the mean value. Out of the nine identified new trends, waste management, sustainability and green building concept and risk management has been identifies as the most important developments over information technology related developments while advanced technological developments were considered with lesser practical applicable value within the Sri Lankan context. Hence, as per the research, it is required to conduct further research studies to acknowledge the time, cost and other benefits can be adopted through facilitating identified innovation and new trends while giving the priority to the high ranked trends identified through this research.

Keywords: *Construction industry; Development; Innovation; New trends; Sri Lanka.*

1. INTRODUCTION

Conceptual changes as well as the technical changes are normally happening in the construction industry. Both developed or developing countries have to face some problems and challenges in the process of adapting and reacting to the changes. As Ofori (2000) mentioned, the construction industry faces to problems and challenges everywhere. But in the developing countries those problems and challenges are more than developed countries and also those problems and challenges become greater in extent and severity with the time. When consider the Sri Lankan construction industry, very limited work had been done, to study the development of the Construction Industry. Nevertheless, it was felt that much has to be done to improve on it being a sector contributing to Gross Domestic Production (GDP) around 9% (ICTAD, 2008). As Paulsen (2008) mentioned, during the industrial revolution, the construction industry had changed at a rapid pace because new advancements in technologies, new tools and new building products had come available to a hungry construction industry faster than ever before. According to Huovila and Koskela (1998), the building industry had to adapt to the new and emerging construction markets which have environmental and social dimensions such as green building concept and waste management. Apart from these concepts, the trends like Building Information Modelling (BIM), Cost Information Management System (CIMS), e-procurement, e-tendering, lean concept, waste management and risk management are also still not implemented to construction industry in a considerable scale (ICTAD, 2008). Compared to the developed countries, it shows a shortage in implementing new trends to the construction industry in developing countries. Similar to the many other developing countries, Sri Lankan construction industry faces numerous challenges when trying to move along with rapidly changing global construction economy. Although it

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is much in need to get the quick adaptation and insertion of novel trends emerging in the world industry, it is rare to be seen the results or progress within Sri Lankan context at the present. The reasons for those failures are challenging to the development of the construction industry in the country and it cause to dropdown the economic development of whole country at the macro level.

2. AIM AND OBJECTIVES

The aim of this research is to identify and promote adoption of development prone novel trends and practices to construction sector. In order to achieve the aim, the objectives were set as; identification of the current situation of development of Sri Lankan construction industry, identification of the new trends in construction industry and to explore the current level of adoption of new trends into the Sri Lankan construction industry.

3. LITERATURE REVIEW

3.1. NEW TRENDS AND PRACTICES IN CONSTRUCTION INDUSTRY

Construction industry is one of the rapidly developing industries in the world. According to the Economy Watch (2010), Construction Industry is one of the biggest and most booming industries in the whole world and this industry is also a potential employment generator and provides work to almost seven percent of the total employed person in the whole world. Therefore the new trends and the new practices are continuously adding to the construction industry. The most recent new trends and practices which have been identified through the literature review are given in the above Table 1 with the respective references.

Table 1: New Trends and Practices in Construction

Trends/Practices	**References**
Green Building Concept	Kibert, (2013); Cohen (2010); Abidin (2009); Jones, Shan and Goodrum (2010); Ahn and Pearce (2007)
Risk management	Kangari (1988); Akintoye and Macleod (1997); Carr and Tah (2001); Wang, Dulaimi, and Aquria (2004); Bosher, Dainty, Carrillo, Glass and Price (2007)
Waste management	Pongrácz, (2004); Kumara and Wijitha (2011), Shen *et al*., (2004); Kofoworola and Gheewala (2009); Tam (2008)
Cost Information Management System (CIMS)	Laudon and Laudon (1991); Albert *et al*. (1990), Wong,A.K.D., (2005); Jun-xia, (2007)
E-procurement	Eadie *et al*. (2007); Vitkauskaite and Gatautis (2008); Eadie et al. (2010); Hardy and Williams (2008)
E- Tendering	Weippert (2003); Tindsley and Stephenson (2008); RICS (2005); Kajewski and Weippert (2004)
Building Information Modelling (BIM)	Bacharach (2009); Smith (2011); Economy Watch (2010); Gu and London (2010)
Nanotechnology	Wang (n.d.); Bartos *et al*. (2009); Mann (2006); Rana *et al*. (2009)
Robotic Engineering	So and Chan (2002); Elattar (2008); Balaguer and Abderrahim (2008)

3.2. ADOPTION OF NEW TRENDS AND PRACTICES TO SRI LANKAN CONSTRUCTION INDUSTRY

Sri Lanka is yet a developing country. Therefore adapting all the new trends and practices in the world construction industry is not practical for a country like Sri Lanka. Yet the requirements for such changes are highlighted in the literature. As an example, Jayawardene (2011) said to the Lanka Business Report that it has to realize that Sri Lanka have not come up with indigenous technologies, sustainable technologies, materials, building components, systems and green technologies and all which is in fact the need of the hour. But it could be observed that some new trends are adopted up to a certain degree into Sri Lankan construction industry. The new concepts like green building construction, risk management and waste management have adapted to the construction industries in the developed countries. But in the Sri Lankan construction industry, it can be seen a less use of these trends. When considering the new trends like CIMS, e-procurement, e-tendering, BIM, nanotechnology and robotic engineering, those trends are not adapted to the construction industries even in the developed countries very well and almost zero percent of adoption to the Sri Lankan construction industry. As Wong *et al*. (2009) revealed, BIM has being increasingly used as an emerging technology in the developed construction industries such as United State, Norway, Finland, Denmark and Singapore and couldn't be seen a implementation in other developing countries in Asia. Confirming the facts, Suh (2010) emphasized that the rates of innovation differ a great deal among nations and even between regions within a nation.

4. Reasons for Non Adoption of New Trends and Practices to Sri Lankan Construction Industry

There are several challenges facing the construction industry when trying to move ahead and adopting of new trends and practices. The main challenges for implementation of those above discussed new trends and practices are given in the Table 2 with the respective references.

Table 2: Challenges for Innovation in Construction Sector

Challenges for implementation	References
Financing capability	Vorasubin and Chareonngam (2007)
Limited credit facilities and high interest rates	Evans (2011)
Misunderstandings	Karunaratne (2010); Pan *et al*. (2007)
Lack of professionals and expertise	Lyons and Skitmore (2004)
Narrow profit margin by contractors	Mincks (2011)
Poor documentation process	Downey (2006)
Poor communication	Emmitt and Gorse (2003);
Low level of usage of Information Technology (IT)	Pamulu and Bhuta (2004)
In-experience	Akintoye and Macleod (1997)
Low level of technology usage	Ashby (2009)
Less government co-operation	Pamulu and Bhuta (2004);
Lack of high technical construction equipment	Lall (1990)
Lack of usage of innovative building materials	Lall (1990)
Lack of skilled workers	Tucker *et al.* (1999)
Lack of Opportunities for Research and Development	Ilter (2007)
Less Support from Institutional Organisations	Bondin (2008)

5. Suggestions to Overcome the Challenges in Sri Lankan Construction Industry Development

It should have to have a certain or likely solution prevailing for any kind of a problem. Therefore it is necessary to take relevant actions to overcome those challenges to achieve the development of construction industry in Sri Lanka through responding to the innovations effectively. The Table 3 presents such suggestions which were identified through the literature review.

Table 3: Suggestions to Improve Adoption of New Trends and Practices into Construction

Suggestion	References
Conduct training programs to construction related professionals.	Edum- Fotwe and McCaffer (2000)
Conduct seminars regarding the benefits in adopting innovation	Ofori (2000)
Conduct workshops, debates etc among undergraduates in the field of construction.	Bondin (2008)
Identify the negative myths regarding usage of innovation in construction.	Pan *et al*. (2007)
Conduct seminars and awareness programs focusing on the identified myths and their validity.	Mansfeild (1988)
Conduct research studies to establish that innovation shall lead to time and cost reduction in construction.	Dulaimi *et al*. (2002)
Get the professional bodies such as IESL, IQSSL etc to identify innovation as a requirement in construction industry.	Blayse and Manley (2004)
Instruct consultancy firms to promote innovation in the construction industry.	Nam and Tatum (1997)
Conduct seminars to major clients to make them aware of the potential benefits on innovation in construction.	Bougrain (2006)
Publish articles on construction magazines on the success stories of using innovation in construction.	Manley (2004)
Introduce National Awards to contractors to award when innovative techniques are implemented.	Pan *et al*. (2007)
Provide concessions and tax benefits to the contractors who are engaged in innovation.	Manley (2008)
Give a considerable priority to the contractors who are involved in innovation in government tender procedure.	Liu*et al*.(2004)
Include clauses regarding innovation in conditions of contracts such as SBD.	Anand (2008)
Introduce criteria in ICTAD registration of contractors regarding innovation.	Anand (2008)
Allocate funds to carry out research studies on innovation.	Ilter (2007)
Provide financial assistance to a certain extent if innovation is considered in projects.	Gollin (1967)
Provide insurance covers specifically for the contractors engaged in innovation.	Anand (2008)
Develop a panel of professionals who are well experienced in the industry to assist contractors who are implementing innovation.	Liu*et al*.(2004)
Provide support and assistance through online solutions through a panel of professionals.	Ilter (2007)
Provide on the job training in foreign countries where innovation is severely practiced.	Gollin (1967)

6. RESEARCH METHOD

Theoretical background of the issue was examined through referring to journals, research papers, conference proceedings, government reports, books, online papers and web sites under the literature survey to define the research gap as the initial step of the research. There are various research approaches such as quantitative research, qualitative research and participatory research (Senarathna, 2012). Here the researchers have followed the quantitative approach. A common way of conducting quantitative research is using a survey. Surveys usually involve filling in of a questionnaire and the usefulness of a survey is that the information obtained is standardized as each respondent, who fills out the questionnaire is answering the exact same questions. Research techniques comprise of data collection methods and data analysis methods. Research methods are concerned with the techniques which are available and those which are actually employed in research project (Fellows and Liu, 2003). A variety of data collection methods can be used in researches. They may include interviews, questionnaires, document surveys, observations, participation and simulation. A well designed questionnaire was used as the research tool being a research falling into the positivist paradigm in research philosophy. Through the survey data were gathered from the industry to rank the new trends in construction industry in accordance with the importance and adoption. Respondents represented the all three main stakeholder categories of the industry namely, contractors, clients and the consultants. There were thirty respondents from each category within the questionnaire survey sample. Researchers used statistical technique to find the mean of the scores collected through the questionnaires survey to rank the importance of new trends in construction industry and level of adoption of those trends in Sri Lankan construction industry practice.

7. RESEARCH ANALYSIS AND FINDINGS

The analysis of data was done in two directions as to rank the importance of new trends and level of adoption of new trends in the Sri Lankan construction industry.

Survey respondents have assigned a score to the each factor identified in the literature chapter through the provided questionnaire. Factors were ranked based on the mean value calculation of the received ranks.

7.1. IMPORTANCE OF THE NEW TRENDS TO THE SRI LANKAN CONSTRUCTION INDUSTRY

The results of the statistical analysis are presented in the Table 4 below.

Table 4: Level of Importance of the New Trend to the Sri Lankan Construction Industry

New Trends	Mean	Rank
Waste Management	4.5778	1
Green Building Concept	4.3444	2
Risk Management	4.0667	3
Cost Information Management System (CIMS)	3.8444	4
e- Procurement	3.2667	5
e- Tendering	3.2556	6
Building Information Modelling (BIM)	2.5222	7
Nanotechnology	2.4667	8
Robotic Engineering	1.9333	9

According to the Table 4, respondents of the survey have identified the most important new trend to Sri Lankan construction industry as waste management. Through proper waste management systems, it could be able to minimize the waste generated through construction industry practices and also waste can be recycled within the construction process itself. Therefore it will lead to minimize the cost of the construction projects. Further, through a proper waste management system it can minimize the overhead cost of a construction project. As a result of that a proper waste management system would become a requirement of the Sri Lankan construction industry. The green building concept has been identified as another important new trend. It has become the second important new trend to the Sri Lankan construction industry as per the collected scores in the questioner survey. Due to the energy efficiency methods and the environmental friendly construction methods of the green building concept, it is considered as an important new trend to the Sri Lankan construction industry having energy crisis as a major challenge for Sri Lanka at present. Construction industry is an important contributor to the economy of the country that has high level of invested money on the construction projects. Therefore it is necessary to have a proper system to minimize the risk of the projects due to the radiant varying nature of the industry. Therefore the risk management is also identified as an important new trend for the Sri Lankan construction industry. Cost information is an important aspect in construction practice. Therefore a system like CIMS is very important thing for the construction industry development. But due to the frequent changes of the cost information, it is difficult to develop such system relevant to the Sri Lankan construction industry and therefore CIMS have achieved the fourth place in the rankings. E-procurement and the e-tendering are having the fifth and sixth rankings according to the collected scores in the questioner survey. The importance of those trends is minimizing the documentation cost and increasing the construction project speed in the pre contract stage. Sri Lanka is rich with its human resources therefore the cost for the professional services and the labor is comparatively less in local; context. Therefore BIM and robotic engineering are identified as with a less importance to the development of Sri Lankan construction industry as the trends replace the human participation. Nanotechnology is also not identified as an important new trend to the Sri Lankan construction industry development by the respondents.

7.2. Level of Adoption of the New Trend into the Sri Lankan Construction Industry

The level of adoption of the new trends in the Sri Lankan context is presented with the ranks obtained, according to the mean of collected scores from the questioner survey. The results can be presented through the table below.

New Trends	Mean	Rank
Risk Management	3.2889	1
Waste Management	3.2444	2
Green Building Concept	3.1667	3
Cost Information Management System (CIMS)	2.7556	4
e- Procurement	2.0778	5
e- Tendering	2.0556	6
Building Information Modelling (BIM)	1.8000	7
Nanotechnology	1.4222	8
Robotic Engineering	1.3000	9

Table 5: Level of Adoption of the New Trend to the Sri Lankan Construction Industry

According to the Table 5, the risk management has identified as the most adopted new trend out of the above all new trends in Sri Lankan construction industry. But the mean level of adoption of the risk management has calculated as 3.2444. It shows that, although the risk management has identified as the rank number one, it even not adapted to the Sri Lankan industry to a greater extent. Shortage of proper risk identifying and management system apart from the various kind of insurance coverage to minimize the risks of the Sri Lankan construction industry might be the cause to the low level of mean adopted level to the risk management. Although the waste management has been used for a considerable time period, the expertise believe that it is necessary a further improvement in the waste management system and due to that reason waste management is also having a less mean adoption level. However waste management has occupied the second place of the rankings among the considered new trends. Green building concept has already adapted to few construction projects successfully in Sri Lankan construction industry. Therefore it has considered as an adapted new trend to Sri Lanka. But due to the less number of projects that has implemented the green building concept, it is expected a more developed level of implementation of green building concept into the construction industry and therefore it is also not identified as a well adapted new trend to the Sri Lankan construction industry. Although there are various kinds of cost databases maintained to use in the future projects by the construction companies, due to the frequent changes of cost information it is difficult to develop a proper CIMS for Sri Lankan construction industry. Further, the new trends like e- procurement and e- tendering are also rarely use in the construction industry. Therefore the respondents have identified e – related trends as less adapted new trends to the construction industry of Sri Lanka. At the same time BIM, nanotechnology and the robotic engineering are identified as very rarely adapted new trends in Sri Lankan context. But due to the mean level of the adoption of all new trends is at a lower level it proves that there is not a sufficient adoption of those trends to the Sri Lankan construction industry.

7.3. Factors which Influence for Sri Lankan Construction Industry Development

Respondents' have assigned a score for each factor according to the level of negative influence it gives in development of the Sri Lankan construction industry. The mean level of influence of each factor according to all the collected scores has calculated and was used to rank the influence of each factor in the analysis. The results are given in the table as below.

Table 6: Factors Influenced to the Sri Lankan Construction Industry Development

Challenge	Mean	Rank
Financing capability	4.6444	1
Limited credit facilities	4.3556	2
High interest rates	4.2778	3
Lack of opportunities for research and development	4.1667	4
Less support from Institutional organisations	3.7889	5
Less government co-operation	3.7000	6
Low level of technology usage	3.6111	7
Lack of usage of innovative building materials	3.4889	8
Inexperience	3.4667	9
Narrow profit margin by contractors	3.3889	10
Lack of high technical construction equipment	3.3111	11
Lack of professionals and expertise	3.2556	12
Lack of skilled workers	3.2333	13
Poor documentation process	3.0111	14
Poor communication	2.9667	15
Low level of usage of Information Technology (IT)	2.8333	16
Misunderstandings	2.7111	17

As per the findings shown in the Table 6, financing capabilities, limited credit facilities and high interest rates are identified as the most challenging factors to the development of the Sri Lankan construction industry. The main idea of this finding can be identified as, that the main challenge to the Sri Lankan construction industry faced when trying to innovate, is the lack of capital cost. Due to this particular reason, the investors are discouraged to invest on the innovative new trends and therefore the implementation of new trends is very slow in the industry. Low level of technology usage, lack of usage of innovative building materials and lack of high technical construction equipment are caused to reduce the implementation capability of new trend to the industry. But the impact of those factors is partially neutralized due to the resource of human labor availability within the Sri Lankan context. Lack of professionals and expertise and the lack of skilled workers is not a major challenge in the Sri Lankan industry because industry has recognized that the level of availability of the knowledge and skills in Sri Lanka is comparatively high than the other developing countries. But unavailability of the opportunities to use the knowledge and skills and the inexperienceness on the innovations has become a challenge to Sri Lanka. Further, due to the narrow profit margins of the contractors and due to the competitiveness of the industry, the contractors also discouraged to do the experiments on the innovations in their projects. Poor documentation process, poor communication, low level of usage of IT and misunderstandings are identified as the less challenging factors to the industry. The industry has confirmed that a good documentation and communication process available in almost all the major construction projects in Sri Lanka. Moreover, the industry has satisfied with the level of usage of IT in construction and documentation process with the use of Auto CAD, MS Office, although it has not sufficiently used to implement the new trends like BIM.

7.4. *Suggestions to Overcome the Challenges to the Sri Lankan Construction Industry Development*

In the survey, the respondents were asked to assign a score for each suggestion according to the level of important to the development of the Sri Lankan construction industry. The mean level of importance of each factor according to the all the collected scores has calculated to rank the importance of each suggestion as this analysis. The results of the analysis are given in the table below.

Table 7: Suggestions to Overcome the Challenges to the Sri Lankan Construction Industry Development

Suggestions	Mean	Rank
Conduct research studies to establish that innovation shall lead to time and cost reduction in construction	4.1111	1
Allocate funds to carry out research studies on innovation	4.0556	2
Conduct training programs to construction related professionals	4.0333	3
Get the professional bodies such as IESL, IQSSL etc to identify innovation as a requirement in construction industry	4.0000	4
Provide concessions and tax benefits to the contractors who are engaged in innovation	3.9778	5
Conduct workshops, debates etc among undergraduates in the field of construction	3.9333	6
Provide financial assistance to a certain extent if innovation is considered in projects	3.8222	7
Conduct seminars regarding the benefits in adopting innovation in construction industry	3.8000	8
Conduct seminars to major clients to make them aware of the potential benefits on innovation in construction	3.8000	8
Instruct consultancy firms to promote innovation in the construction industry	3.7111	10
Provide insurance covers specifically for the contractors engaged in innovation	3.6333	11
Include clauses regarding innovation in conditions of contracts such as SBD	3.6000	12
Introduce a criteria in ICTAD registration of contractors regarding innovation	3.5889	13
Introduce National Awards to contractors to award when innovative techniques are implemented	3.5556	14
Develop a panel of professionals who are well experienced in the industry to assist contractors who are implementing innovation	3.4667	15
Give a considerable priority to the contractors who are involved in innovation in government tender procedure	3.4556	16
Provide on the job training in foreign countries where innovation is severely practiced	3.4000	17
Publish articles on construction magazines on the success stories of using innovation in construction	3.3333	18
Identify the negative myths regarding usage of innovation in construction	3.2667	19
Conduct seminars and awareness programs focusing on the identified myths and their validity	3.2222	20
Provide support and assistance through online solutions through a panel of professionals	3.1000	21

As per the results given in the Table 7, conduct research studies has been identified as the foremost requirement. In establishing the innovation it will lead to time and cost reduction in construction to improve quality of the final products. Allocation of funds to carry out research studies on innovation is identified as the second most important suggestions to develop the construction industry to implement the innovations. Financial incapability is the major challenge to the Sri Lankan construction industry development in responding to the innovations and therefore it is necessary to aware the industry about the time and cost benefits of the innovations to encourage the implementation of them. Further, it is necessary to provide financial assistance to encourage the researchers to conduct such researches. In addition, it is important to improve awareness and train the construction industry related professionals to implement the innovations successfully into the Sri Lankan construction industry. Therefore conducting training programmes and CPDs to construction related professionals, and getting involvement of the professional bodies such as IESL, IQSSL etc to identify innovation as a requirement in construction industry. It is necessary to encourage the contractors who do the experiment on implementation innovation in the project to increase the uses of new trends in the Sri Lankan construction industry. Moreover it is required to encourage the projects that innovations are implemented with providing concessions and tax benefits etc. and also to the contractors who are engaged in innovation and providing financial assistance to a certain extent. Awareness of the benefits of the usage of innovations is identified earlier as a way to the implementation of new trends successfully. Therefore, it is needed to aware the clients about the benefits of the innovations will be important step towards bringing in innovation. In addition, there is a major role for the consultant organizations to promote innovation practices as those are the organizations that does the designing works of the construction projects. Therefore, conducting seminars regarding the benefits in adopting innovation in construction industry, conducting seminars to major clients to make them aware of the potential benefits on innovation in construction and instructing consultancy firms to promote innovation in the construction industry were also seen as important suggestions to the construction industry development. However, it has caused to receive a middle level of importance in the rankings to those suggestions being the reason that industry has a doubt about the impact that can be done by the seminars to change the construction industry. However, according to the findings in Table 07,it is visible that mean level of the importance of all the identified suggestions higher than the 3.It has proved the viability and the importance of all of the suggestions to the Sri Lankan construction industry to create better response for the innovation adoption.

8. CONCLUSIONS

Sri Lanka as a developing country was always claimed to be low responsive to innovation in the construction sector. The research was initiated with the identification of the level difference between the implementation of new trends for the construction industry in Sri Lanka compare to the developed countries. Researcher identified this as a challenge to the development of the construction industry in Sri Lanka. Therefore the research aimed to identify the new trends of the construction industry, the adoption of those new trends to Sri Lankan construction industry, barriers to adopt new trends t and the suggestion to overcome the barriers. As the second step of the research, researcher has identified a list of new trends of the construction industry, implementation barriers of new trends and came up with the suggestions for evade the barriers through the comprehensive literature survey. With the intention of identifying the importance and the viability of identified factors for the Sri Lankan construction industry, questionnaire survey was conducted with which has gathered the ideas of ninety respondents who are representing the contactors, clients and the consultant in the construction industry of Sri Lanka. The mean score of each factor has calculated for ranking the importance and the viability of the factors to the Sri Lankan construction industry at the analyzing chapter and identified the waste management, green building concept and the risk management as the most important new trends to the Sri Lankan construction industry and same time it has evaluated their adoption to the Sri Lankan construction industry. According to the findings the adoption of those new trends into the Sri Lankan construction industry is at a miner level. Furthermore research has discovered the major barrier to the adoption the innovations to the Sri Lankan construction industry as the less motivation of the investors invest on the innovative trends due to the lack of capital cost and finally identified the conducting research studies to establish that innovation shall lead to time and cost reduction in construction and motivate the researchers to conduct the research studies on innovations are the important actions needed to implement to develop Sri Lankan construction industry through response the innovations. Therefore it is expected that implementation the findings of the research would be contributed on the Sri Lankan construction industry development.

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EFFECTIVE FIRE SAFETY PLANNING FOR INDUSTRIAL BUILDINGS: A LITERATURE REVIEW

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ABSTRACT

The lives and health of human beings, the growth and prosperity of organisation, and the increasing need for fire safety are immediate concerns which provide the original momentum for the business continuity of the organisation. Fire safety consideration should form an important part of any new product or technology development to promote sustainable development, and acceptable solutions to acute fire safety concerns must not pose a threat to the long term development. Simply, the fire safety and sustainable development has common interest in making sure that fire safety is achieved in the most sustainable way. However, the direct property damage to the buildings due to ineffective fire safety planning is increasing with the development of industrialisation and urbanisation. This paper therefore aimed to develop a conceptual model for effective fire safety planning for industrial buildings. A comprehensive literature review was used as the research methodology for this paper. Keywords search for fire accidents causes for fire accidents, fire safety planning and industrial buildings were used to search the literature. The literature findings highlighted that many buildings such as factories do not arrange regular drill; therefore the workers discover themselves in an alien situation whenever an emergency situation arises, causing panic, stampede etc. which further escalate the degree of casualty. Further, accidents are caused mainly due to technical failures and human failures where human failures include lack of awareness of the safety precautions required, inadequate expert knowledge and qualifications in accident prevention. Failure to effective planning for fire safety in buildings can hinder the recovery process, whereas recognition of its importance leads to more efficient use of resources in the wake of emergencies

Keywords: *Fire Safety; Industrial Buildings; Planning.*

1. INTRODUCTION

The greater understanding of the issues and dialogue between the varieties of disciplines can help make the buildings safer and more sustainable. Safety is the complement or antithesis of risk and if safety will increase then the risk is reduce (Ramachandran, 1999). Fire accidents cause fatal and serious injuries to occupants of the building and direct material damage to the building and other assets of the building (Subramaniam, 2004). The likelihood of the occurrence of an accidental fire and its consequential loss will depend on the standard of precaution measures and whether appropriate emergency actions have been taken (Tsul and Chow, 2004). Innovative building methods lead to concerned about choosing the safest and most effective fire safety planning strategy when attending a fire.

Effective fire safety planning prevents the occurrence of fire by the control of fire hazards in the building, ensures operation of fire protection systems by establishing maintenance procedures, and provides a systematic method of safe and arranged evacuation of the building in the event of fire. However, currently buildings have become more complex, thus a more effective approach to industrial fire safety is needed to deal with the complexities and changers that exist in modern industrial facilities (Zalosh, 2003). According to the Lin (2005), Taiwan shows that industrial occupancy has the highest annual rate of probability of fire occurrence than other building categories. Moreover, Fire Service Department of Sri Lanka (2011) highlighted that fire hazardous in industrial buildings are

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higher than other building categories. Thus, this study was focus on effective approach for fire safety planning in industrial buildings.

2. LITERATURE REVIEW

2.1. FIRE SAFETY

Fire Safety imposes on nearly every aspects of human endeavor. The term, fire safety refers to fire prevention, limiting the spread of fire and smoke, extinguishing a fire and the chance of a quick and safe exit (Kobes *et al.*, 2010). As described by Hassanain (2006), fire safety is the reduction of the potential for harm to life as a result of fire in buildings (CWC, 2000 cited Hassanain, 2006). Hence, fire hazards with numerous casualties generally raise questions about the safety requirements in buildings with the type of occupancy levels that there were in the property wherein the fatal fire occurred (Kobes *et al*., 2010). Moreover, Porter (1990) stated that in order to achieve the highest fire safety level in a building, it is necessary to have a greater reliance on what are known as active fire safety systems such as automatic sprinkler systems, smoke detection systems and smoke control systems.

The consequences of poor fire safety practices and a lack of emergency planning are especially serious in properties where processes or quantities of stored materials could pose a serious threat to the community and environment in the event of fire hazardous (FireSafety Planning for Industrial Occupancies, 2000). Marchant (2000) pointed out the objectives of fire safety as Life safety; the protection of the contents of a building; the protection of the building fabric and The minimization of threat to the environment. All these objectives highlight one main objective that is to prevent ignition.

Several major disasters, such as fire at the Manchester Airport (UK, 1985) and the fire incident in the channel tunnel (UK-France, 1995) etc. have highlighted the need of improving safety performance in any facility (Santos-R and Beard, 2001). Fire safety is also a matter of Sri Lanka due to rapid increment of fire hazardous with the industrialization and urbanization. According to the Fire Service Department of Sri Lanka (2012), 10% growth of fire hazardous from 2007 to 2011 can be seen. In fact, achieving fire safety in the built environment requires contributions from a number of organizations and during the operational stage building should be maintained and operated in accordance with the effective fire safety planning (Wang, Marsden and Kelly, 2011).

2.2. FIRE SAFETY PLANNING

Fire safety planning prevents the occurrence of fire by the control of fire hazards in the building, ensures operation of fire protection systems by establishing maintenance procedures, and provides a systematic method of safe and orderly evacuation of the building in the event of fire (Fire Safety Plan-British Colombia, 1998). Effective planning strategy is crucial to ensure a safe built environment for occupants'. Fire Safety Plan, British Colombia (1998) further stated that fire safety planning basically has three objectives, namely; Fire Hazard control; Fire Protection System Maintenance; Emergency Evacuation. Thereby, a proper fire safety plan is need to be developed in order to achieve these objectives. According described by Tsui and Chow (2004), a fire safety plan should comprise with at least following four plans.

- Maintenance plan
- Staff training plan
- Fire action plan
- Fire prevention plan

Santos-R and Beard (2001) asserted that fire safety can be planned according to four safety levels (as shown in Figure 1) of achievement and planning is continues process of decision taking, whereby resource allocations are made.

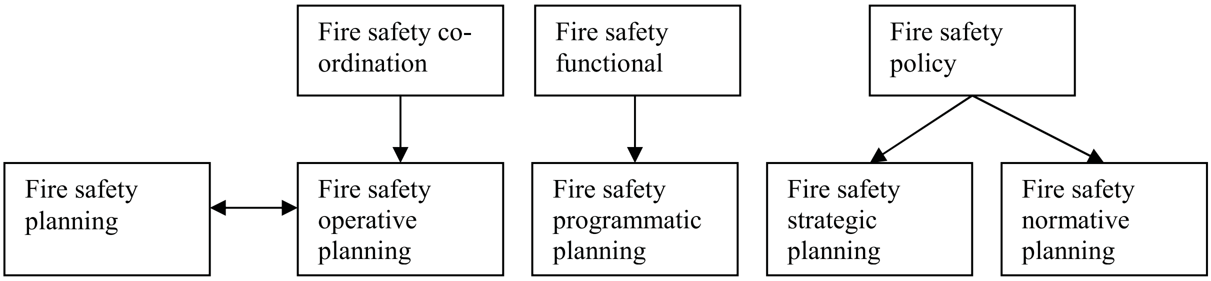

Figure 1: A Fire Safety Management System Performance Measurement System (Adopted from Santos-R and Beard, 2001)

As per the Tsui and Chow (2004), a complete fire safety plan should be formulated to cover following five major components to give five sub-plans

- Documentation, information record and review plan
- Maintenance of fire safety measures and fire prevention
- Staff training
- Emergency action procedures
- Assessment on building alternation/addition.

Hassanaim (2006) highlighted that fire safety planning must do with knowledge of the occupancy profiles of their facilities. Moreover, fire safety planning should be updated with requirements to accomplish the highest degree of safety level. Moreover, Marchant (2000) acknowledged that fire safety planning should be carried out separately from fire safety designs in many cases after the design is complete. Effective fire safety planning specially for industrial building is very much crucial as facilities such as industrial buildings have greater possibility for unplanned incidents such as fire disaster (Ripple, 2003; Alexander, 2005).

2.3. FIRE SAFETY PLANNING IN INDUSTRIAL BUILDINGS

Fire safety is a function of the design and use of the building, but also and importantly, how the facilities are manage day to day and how well plan active fire safety systems are the good indices to assess the level of fire safety (Shields, Boyce and Silcock, 1999). It is commonly believed that improper design, high population load and mismanagement of floors and circulation systems in industrial buildings are major contribution to fire hazardous (Firoz, 2011). According to the Lin (2005), industrial buildings define as buildings where the main activity is for processing, manufacture or repair although there may also be a part of the building used for storage, offices of some other purposes.

Facilities such as factory buildings have greater possibility for unplanned incidents such as fire disaster than do commercial facilities (Ripple, 2003; Alexander, 2005). According to the statistical data of fire calls (Fire Service Department, Sri Lanka, 2009), 10 fire emergency calls received from factories out of 49 fire emergency calls received from industrial buildings. No of fire accidents reported to the Fire Service department are increased by 14% by the end of 2010 and records further revealed that it was 20 fire emergency calls out of 49 fire emergency calls (Fire Service Department, Sri Lanka, 2010).

Facilities such as factory buildings have greater possibility for unplanned incidents such as fire disaster than do commercial facilities (Ripple, 2003; Alexander, 2005). According to the statistical data of fire calls (Fire Service Department, Sri Lanka, 2009), 10 fire emergency calls received from factories out of 49 fire emergency calls received from industrial buildings. No of fire accidents reported to the Fire Service department are increased by 14% by the end of 2010 and records further revealed that it was 20 fire emergency calls out of 49 fire emergency calls. Recently, World Trade Organisation (WTO) has ranked Bangladesh as the 4th largest exporter of readymade garments in the world. This sector contributes for 75% of foreign currency earning for Bangladesh. This industry has played a significant role in elevating economic and living standard of millions of families all over the country. Along with bringing blessing for the nation, textile and readymade garment industry also hold the record of experiencing some worst industrial fire accidents in the country (Ahamed and Hussain,2010; Firoz, 2011). Further, as explained by Ibem (2011), in Nigiria 29.17% of disasters are occurred in built facilities due to the fire hazardous that is mainly due to the poor fire safety planning.

The cause analysis for most of the fire accidents in industrial buildings shows that many accidents have occurred due to technical and human failures where human failures include lack of awareness of the safety precautions required, inadequate expert knowledge and qualifications in accident prevention, poor guidance (Ahmed and Hossain, 2009). Further, a study by Bryan (2002) highlighted that the size of a fire is related to the behaviour of the personnel in the building either before or during the incident. These entire causes highlight the absence of effective fire safety planning in industrial buildings. Failure to address this issue for fire safety in a building can hinder the recovery process whereas recognition of its importance leads to more efficient use of resources in the wake of emergencies (Rick *et al*., 2007). Thus, effective approach for fire safety planning in industrial buildings is becoming the crucial fact to concern.

3. DISCUSSION

The result of literature on this subject matter have revealed some vital issues that require to addressing though effective approach. In fact, results show that the most prevalent fire hazardous is related to the Industrial sector. In order to be more considerable for industrial occupancies, there is a need to look into this matter more seriously as it directly relates to human lives. Fire safety planning basically involves four levels where all these four levels are needed to be addressed as described in below Figure 2 for effective fire safety planning.

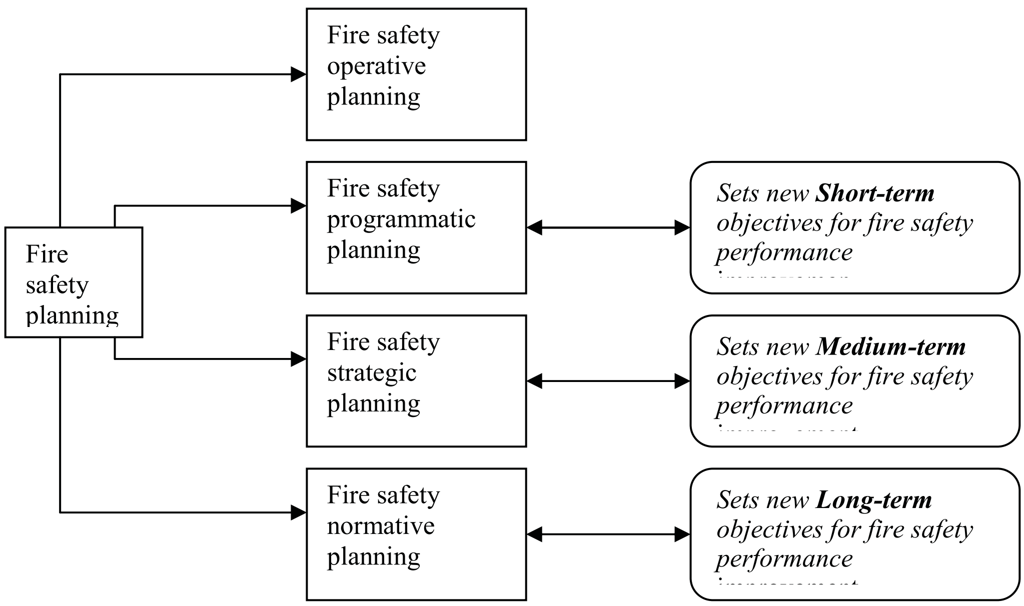

Figure 2: Levels of Fire Safety Planning

- **Fire safety operative planning**: In this kind of planning, there is no fire safety performance improvement or change, but it accepts the existing status of fire risk as it is in the organisation's operation.
- **Fire safety programmatic planning**: New short-term objectives for fire safety performance improvement should be developed at this level and necessary actions should be taken to achieve

them. However, these objectives can be achieved without extra investment; that is, they can be achieved with existing resources and under existing constraints.

- **Fire safety strategic planning**: It sets new medium term objectives for fire safety performance improvement, but they can only be achieved with some minor investment to eliminate current constraints.
- **Fire safety normative planning**: This planning process involves setting long-term fire safety objectives. To achieve these objectives, organisations will need to commit major investment to develop new technologies, new equipment or process.

However, many challenges are involved in effective fire safety planning. Major challenge of fire safety planning is about identifying the changes that may happen in the future. As per Meacham (1999), the types of material stored in a warehouse may change over time, and production equipment may change in industry hence, identifying those changes in planning stage is a real challenge. Moreover, local codes on the active fire safety systems change at different times and would have different requirement (Chow and Lui, 2002). Hence, anticipation of future legislative requirement in planning stage is a greater challenge. Gibson (1997) pointed out that it is always necessary to ensure that design criterion of building agreed with the building which is actually occupied, mostly actual situation and design situation may change. Instead of that addressing those challenges in planning stage is important fact to concern.

4. RESEARCH METHOD

A comprehensive literature was used as research methodology for this research paper. Information relevant to the keywords such as fire safety, fire safety planning, industrial buildings were obtained through various sources such as journal articles, online journals, e-books, web sites, electronic library data base and other publications

5. CONCLUSIONS

Fire safety is a highly national and international issue where industrial buildings need to focus this as one of the major risks which has negative impact on business continuity. The research findings highlighted some of the interesting and crucial challenges that are encountered when carrying out fire safety planning. It is further revealed that probability of fire occurrences in factory buildings is higher than other building categories. Many factories do not arrange regular drill; therefore the workers discover themselves in an alien situation whenever an emergency situation arises, causing panic, stampede etc. which further escalate the degree of casualty. For the purpose of achieving higher degree of safety of occupants, property and environment, effective fire safety planning is required. Effective approach for fire safety planning in industrial buildings is becoming the crucial fact to concern. Based on the literature findings, a conceptual model is developed to emphasise how industrial facilities should effectively plan their fire safety systems which will help them to achieve the highest degree of fire safety in order to safeguard the lives, property and environment.

Focus of this study is only limited to fire safety planning in industrial buildings, and the primary data comprises only the literature findings. This made it difficult to provide empirical evidence to support the findings. Future research could consider a quantitative research or quantitative research on this area involving many local and foreign industrial firms operating in Sri Lanka.

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EFFECTS OF PREMATURE TERMINATION: CASE STUDIES OF SRI LANKAN CONSTRUCTION PROJECTS

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ABSTRACT

Construction projects are inevitable. But they should be in proper way. However some of projects/contracts come to end before their actual completion. This is an adverse effect to the construction industry and it can be identified as a barrier for sustainable construction. Therefore there is a requirement of avoiding occurrence of adverse premature contract/project termination and mitigating their effects while promoting sustainable construction practices. Hence, the aim of the research is to investigate effects of premature contract/project termination before minimizing adverse effects.

In accordance with existing literature, mainly three types of Contract termination can be identified as, termination due to default of client, termination due to default of Contractor and termination for convenience of Employer. But, contract/project terminated prematurely due to whatever reasons, their issues affect on many ways to project stakeholders. Further, less attention is given to some issues relating to project/contract termination like impacts of termination, relationship among parties after termination and steps to prevent premature termination.

This research is conducted through three case studies of terminated construction projects in Sri Lanka. To gather data, semi structured interviews were carried out with professionals and unstructured interviews were held with technical employees. Further, three experts were interviewed to clarify compatibility with termination concept.

The findings were revealed that there are good impacts as well as bad impacts on stakeholders due to premature project/contract terminations. Most of the time, it results in breaking the relationship among parties, creating disputes, blacklisting the contractor…etc. Further, the research is explored good practices for prevent adverse termination effect which can be implemented in construction industry.

Keywords: *Mitigating Termination; Premature Contract Termination; Premature Project termination; Sri Lanka.*

1. INTRODUCTION

Due to the complex nature of the construction projects, the risk involvement of them is very high. According to the Employer's requirements and within restricted budget, it is very difficult task to achieve blameless out come by Contractor. The project is defined by Nicholas (2001) as, activities of limited duration and all projects come to an end.

Contracts are made to be performed by the responsible parties. When parties enter in to a contract, they have to perform it as expected by its' terms. Indeed, a contract consists of a number of terms which determine the scope of the performance obligations, which the parties have accepted. A failure to perform in accordance with these terms is a breach of contract, which will entitle the other party to have an appropriate remedy based on the contract (Mckendrick, 2007). Thereupon as a remedy, termination of the project can be raked by either party. According to the Smith and Sims (1985), termination of a contract occurs, where a valid and enforceable contract is brought to an end prematurely, either by it becomes impossible of performance by circumstances which were unforeseeable at the time the contract was formed or by the actions of one or both parties.

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Termination of construction projects often results in many problems like claims, disputes and issues to project stakeholders. Therefore, the decision to proceed with that option should not be taken lightly (Interface Construction Consultancy, 2009).

Termination of a project is inevitable, but the way of termination will incur long lasting impact on the project stakeholders which cannot be predicted. The success of future projects may depend on not only the success of past ones but also on how unsuccessful projects were treated by the organization and its stakeholders (Amir *et al*., 2000).

Premature terminations of projects are very adverse incidents in construction industry. As per Yogeswaran (2004), termination of construction project directly affect to the economic growth of Sri Lanka. Also termination on construction projects often result in many problems and issues to project stakeholders as well as claims and disputes (Interface consulting International, 2009). Besides, researchers were able to identify the research gap about effects of premature termination of construction projects in Sri Lanka. Therefore as a developing country, it is essential to avoid premature terminations in Sri Lankan construction projects to drive towards more developed and sustainable construction industry. For the purpose it is useful to study what are the effects of premature terminations of construction projects in Sri Lanka and use them as lessons for future projects.

2. LITERATURE REVIEW

2.1. PROJECT TERMINATION

There are two general types of termination typically addressed in construction contracts namely, termination for convenience and termination for cause, which is sometimes referred to as termination for default.

In accordance with Interface Construction Consultancy (2009), in a termination for convenience, the owner may terminate the contract for whatever reason such as economic/business reasons, or as the most expeditious way of eliminating a non-performing Contractor with minimum risk of a legal dispute.

Cause for termination may occur when the owner believes the Contractor has not performed according to its contractual obligations and thus has materially breached the agreement. Some of the more commonly cited reasons for terminating a contract for cause include the following:

- Failure to pay labor, subcontractors, vendors, or material suppliers
- Failure to meet the project schedule or diligently perform the work
- Defective or deficient performance
- Failure to follow applicable laws or regulations
- Failure to consistently follow safety requirements

Premature project/contract termination is able to occur from both type of termination. When project is terminated prematurely, there are many issues which will have to face by many parties.

2.2. REASONS FOR PREMATURE PROJECT/CONTRACT TERMINATION

Factors affecting to termination can be discussed under following sub headings.

Breach of contract

Treitel (2003 cited Mckendrick, 2007, p.389) defined the breach of contract in the following terms “a breach of contract is committed when a party without lawful excuse fails or refuses to perform what is due from him under the contract, or performs defectively or incapacitates himself from performing”.

As instances for breach most common in practical,

- Irregular payments to Contractor
- Poor performance of Contractor or who is not worked following specifications
- Do not maintain performance bond according to contract or do not extend its validation at the time extension granted
- Unnecessary delay in construction
- Sub contract part or whole of work without intention of Engineer

Disputes affecting toward termination

In most recent research, Arulnesan (2010) has presented that how and what disputes are mostly affected toward the project termination. The most common classification of type of disputes that have been seen in contractual relationship is summarized as follows,

- Relationships and people's conflict in the industry
- Financial matters (claims & payments)
- Standard of the workmanship (design & manual works)
- Time related disputes

Legal restrictions and injuctions

As another factor affect to the project termination as legal restriction and injuction explained by Murugathasan (1993) as follows. A building must be designed and built according to the policies and regulations formulated by the following institutions.

- Law enacted by parliament
- Local authority's regulations
- Fire department's regulations and requirements

Impossibility of performance can be resulted from the intervention of the above mentioned laws and regulations it may help to terminate the project. A contract may terminated due to the negligence of the professionals when;

- In the pre design stage neglect survey of the land, levels, drains, soil conditions and neglect survey of the existing buildings
- In the design stage neglect the design of the architect or his staff
- Negligence in service such as failure to advice client on any consent necessary from superior or adjoining land lords, failure to obtain any statuary consent, for planning building regulation, land commissions, fire authority.

2.3. Reasons for Premature Project/Contract Termination

The impacts due to premature termination can be discussed as follows;

Impacts on organization

Hormozi, McMinn, and Okeleke (2000) stated that, organizing for a project's termination process is especially important when it has failed, because of the lasting impact on future projects as well as the organization's image. Including project team members to the termination process will increase their loyalty and commitment, not only to the organization but also to the success of future projects.

In addition, Bommerand Pease (1991) showed that although the reasons may vary, the impact is frequently the same. Project cancellation can affect employee productivity, the reputation of the firm, and the value of the firm's stock. Although, there is little thing of employee productivity and project cancellation, project team's perception of the cancellation may influence their productivity for the next several years.

Impacts on professionals

How a project is viewed within the organization is also very important. Because corporate resources can be very limited, projects that are perceived to be draining scarce resources tend to undercut morale. Other project teams envy the resources "squandered" on unproductive or failing projects. This, in turn, leads employees to question the wisdom of senior management (Mandelland Murphy, 1989), and reduces their productivity and level of commitment to the organization (Hormozi, McMinn and Nzeogwu, 2000).

Impacts on economic growth

In Sri Lanka, Silva *et al.* (2005) states that the construction industry is a major contributor to the development of economy contributing around nine percent (9%) to the Gross Domestic Product of the country. Due to this fact construction industry plays one of major role as a key component of the economy. Improving construction capacity and capability is important to most developing countries (Yogeswaran, 2004). However, premature termination of construction projects/ contracts effects country’s economic growth badly by reducing construction capacity and capability.

3. RESEARCH METHODOLOGY

This research was conducted using a qualitative approach which consists with literature survey, semi structured interviews and expert survey. At the beginning of the research, researcher broadly investigated the background of research referring journal articles, books, unpublished dissertations and e-resources to get comprehensive knowledge about reasons for project termination. A comprehensive literature review conducted exploring types of project termination, factors to project termination, process, and identified the issues from the premature project termination filling gap by emphasizing significance of research problem.

Collected data analyzed in accordance with code based content analysis using NVivo software. Content analysis involves coding and classifying data. Some authors refer to this as categorizing or indexing. The basic idea is to identify from the transcripts the extracts of data that are informative in some way and to sort out the important messages hidden in the mass of each interview (Hancock, 1998).

Then such issues are interpreted by cognitive map. Eden and Ackermann (2002) stated that, cognitive maps thus take the form of a set of connected options outcomes chains. Assertions about the world imply possible policy options which (taken in coherent bundles) in turn imply strategies for the organization. These are often linked to the overarching goals taken to be purposes of the organization or decision maker. In building a map, then, it is important to ask at each and every stage what the proper place of a concept is within the map.

Cognitive map interprets clear idea of large data set as briefly by form of model and form of relation among each factor depict by arrows. Then reader can get idea about data content just looking at cognitive map.

4. RESEARCH FINDINGS

Data collection was done selecting three cases and details of those cases are given briefly as bellow;

Table 1: Details of Selected Projects

Project	Project A	Project B	Project C
Initial Type	Apartment Building project	Building project	Building project
Project cost (Rs.)	1.6 billion	11.5 million	7.5 million
Duration	4 years	6 months	6 months
Procurement Method	Measure and pay	Measure and pay	Measure and pay
Client	Private	Public	Public
Contractor	Private	Private	Private
Remarks	Project is converted to City Hotel	Scope is not change	Scope is not change

4.1. FACTORS AFFECTING TO TERMINATION

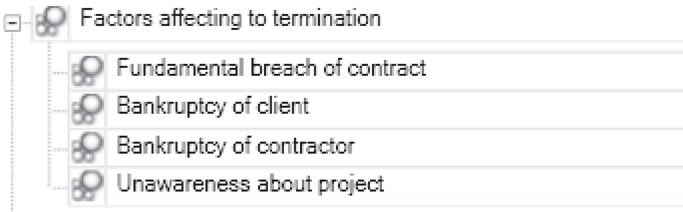

Figure 1: Coding Structure for Factors Affecting to the Termination

Four factors affecting to termination were identified as, fundamental breach of contract, bankruptcy of Client, bankruptcy of Contractor and unawareness about project through research findings. According to the findings brancrupcy of the Client of project A was due to decreased market demand for the project. On the other hand, brancrupcy of Contractor in project B and C where the Contractor got both the projects by using fake process, was due to unawareness of his financial capability and poor cost management among projects.Unawareness of Conditions of Contract and carelessness on contract was lead Contractor of Project B and C to terminate the contracts under fundemental breach of contract.

4.2. IMPACTS DUE TO TERMINATION

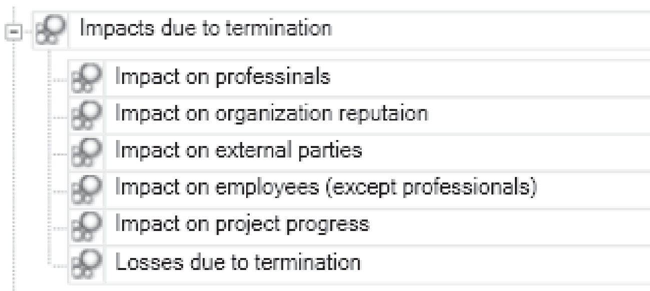

Figure 2: Coding Structure for Impacts due to Termination

Mainly six impacts were identified via research findings as, impacts on professionals, impact on organization reputation, impact on external parties, impact on employees (except professionals), impacts on project progress and losses due to termination. Impactsfor professionals could be identified as accusing by administrators and increasing additional workload, while delaying completion of project and money flowing for dispute resolution methods were directed to impact on project. Further, blacklisting contractor's company toward to reputation of firm and employees lost their jobs due to bankrupting of firm.

4.3. REASONABLENESS OF TERMINATION

Figure 3: Coding Structure for Reasonableness of Termination

Reasonableness of termination mainly depended on the reasons of termination and following Conditions of Contract when proceeding termination process. In accordance with the selected cases, bankruptcy of client/contractor and careless cost handling cause to emerge termination. Additionally, adopting experts' ideas also helped to enhance the validity of the termination process. In accordance with circumstances, each party has responsibilities and obligations to terminate particular project. It may vary Contract to Contract in accordance with their complexity, size and risk. Several Standard Conditions of Contract such as Standard Bidding Documents in Sri Lanka and FIDIC Conditions give standard path to follow at termination procedures with respect to nature of projects.

4.4. RELATIONSHIPS AFTER TERMINATION

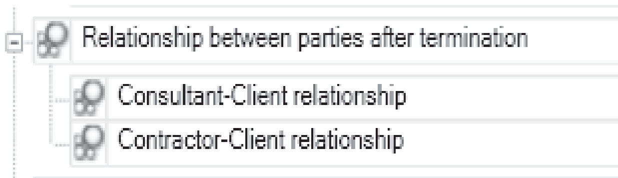

Figure 4: Coding Structure for Relationship between Parties after Termination

General concept is that termination makes bad to parties. It results in breaking the relationship among parties as well. Further, Clients are unwilling to award projects to Contractors who have connected with termination circumstances. By research findings researcher was able to identify that there was a good relationship between the parties after the termination of project A whereas there were bad relationships after termination of Project B and C. This various circumstances depend on mutual understanding of each party about the termination situation.

4.5. OTHER ISSUES DUE TO TERMINATION

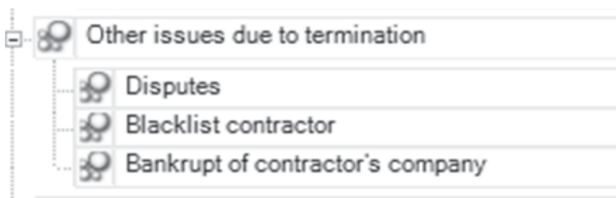

Figure 5: Coding Structure for Other Issues due to Termination

Disputes are the main issue at the project/contract termination. Disputes can be raised due to unfulfilled entitlement of either party. Then each party has to find solution through ADR methods.At Project B and C, when going through disputes resolution method, Contractor was blacklisted after informing by Client to the ICTAD (institute for Construction Training and Development). Even though, the Contractor was removed from the blacklist after settling the dispute amicably, itwas serious damage to the reputation of Contractor. The whole construction company of Contractor of Project B and C was bankrupted due to his careless cost control and fraudulent behavior.

4.6. ADVERSE TERMINATION MITIGATION

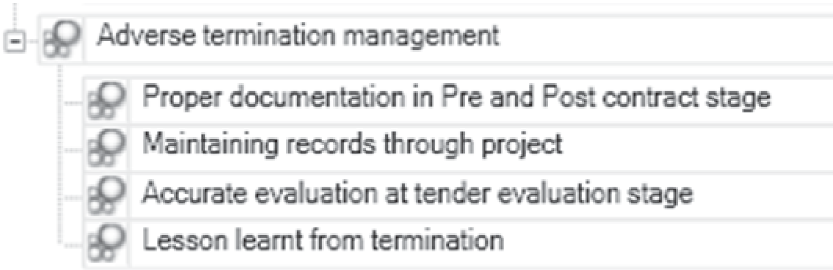

Figure 6: Coding Structure for Adverse Termination Management

Each issues regarding termination can be categorized as bellow in accordance with selected projects.

Table 2: Summary of Termination Factors According to Each Project

Issues	Project A	Project B	Project C
Type of termination			
Default of Contractor		√	√
Default of Client	√		
Factors affecting to termination			
Bankruptcy of Client	√		
Bankruptcy of Contractor		√	√
Not maintain progress of project		√	√
Withhold payment		√	√
impacts due to termination			
Blacklisted Contractor's company		√	√
Loss of employment		√	√
Accused by Client		√	√
Wasting money for dispute resolution		√	√
Changing scope of project	√		
Delaying project progress		√	√
External impacts and effect			
Political impacts		√	√
External party is unable to recover loss		√	√
External party is able to recover loss	√		
Reasonableness of termination			
Use of Conditions of Contract		√	√
Using alternative process at termination situation	√		
Relationship after termination			
Fair and good relationship among parties	√		
Bad relationship among parties		√	√
Lesson learnt from termination			
Disputes resolved in house caused to good effect	√		
Weak maintaining of documentation through each project phases caused bad effects		√	√
Continuing same parties to future work of project caused good effects	√		

5. CONCLUSIONS

Project/contract termination is mainly done in three ways as default of Contractor, default of Client and for the convenience of Client. The factors which were identified by research can be presented in common way as, fundamental breach of contract, bankruptcy of Client, bankrupt of Contractor and unawareness of project. The legal injuction and restriction and disputes which were discussed in literature review are not toward termination of selected cases. But in some cases disputes were raised after and during termination process. Fundamental breach of contract can be interpreted as not submitting updated project programme and withhold Contractor's payments which cause disputes.

Termination impacts of the above cases and their attitude to termination are given commonly. The issues of project/contract termination can be indicated as impact on professional's work and their position, impact on Contractor and Client, impact on Contractor's employees, impact on reputation of Contractor's and Client's organization, impact on external parties who are expecting services, impact on project progress and losses due to termination. In some circumstances, administrators are unwilling to adopt Conditions of Contract related to termination, as their concept of termination is only for negative side.

Reasonableness of project/contract termination depends on process which followed by each party to enter into termination process. Conditions of Contract establishs standard rules and obligations of each party to proceed with contract termination situation.While, regarding relationship among parties, general comprehension is that there are bad relationships among parties after the termination situation.

Finally these termination situations should not be limited to past ruins. Their attitude and impaction should be taken as example to all members of construction industry to mitigate these adverse premature project/contract terminations.

6. RECOMMENDATIONS

This research disclosed a way towards the mitigation of the premature project/contract terminations in construction industry which were mainly affect to lay Contractors and Clients in to critical financial situation. Further, this study helps to gain good practices and attitudes for key members of contracts.

Followings can be recommended as implications for the construction industry as sustainable construction practicesand this study is expanded further by identifying mechanisms to improve and enhance professional experience on project/contract termination.

- Maintaining project's records regularly
- Disputes are tried to be solved by amicably or mediation
- Follow the contract and prevent fundamental breaches
- Get best effort to minimize effect to external parties
- Establish clear contract documentation
- Contractor's awareness of his financial capability
- Carry out preliminary market survey before investing to the project
- Impartiality of Engineer and resistance to political impacts

7. FURTHER RESEARCHES

- The applicability of Conditions of Contract for conversion of project
- External factors affecting to termination of Contracts in government projects
- Impact of Sub Contract termination

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ENABLERS AND BARRIERS OF IMPLEMENTING ISO 50001- ENERGY MANAGEMENT SYSTEMS (ENMS) IN SRI LANKAN CONTEXT

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ABSTRACT

Energy is critical to organizational operations and can be a major cost to organizations. Besides the economic costs, energy crisis can impose various environmental and societal costs by reducing resources and supporting environmental problems. Especially in buildings, energy is considered as one of the main cost centres for their operations. Considering the importance of managing energy, a number of national, regional and international Energy Management Systems (EnMSs) have been developed to integrate energy efficiency into organisations' management practices while fine-tuning operating processes and improving efficiency of industrial systems. Among them, ISO 50001-EnMS, which was introduced by International Organization of Standardization (ISO) is the most popular system which has been implemented all over the world. However, literature and preliminary studies revealed that there are very few ISO-50001-EnMS applications within Sri Lanka. Hence, there is a little doubt relating to the implementation of ISO 50001-EnMS in Sri Lankan Context. Therefore, the aim of this paper is to critically review the enablers and barriers of implementing ISO 50001-EnMS in Sri Lankan context. A comprehensive literature review, desk study and a preliminary expert survey were employed in achieving the aim of the paper. The research findings identified that financial constraints; lack of experts relating to EnMSs; unawareness on the importance of applicability; complexity of documentation processes; institutional complexities and different cultural aspects as the most critical barriers while identifying the improved organizational image; well-documented energy utilization procedures; regulatory compliances and internal/external recognition and rewards as the key enablers for the implementation of ISO 50001-EnMS in Sri Lanka.

Keywords: *Energy Management; ISO 50001-EnMS; Sri Lanka.*

1. INTRODUCTION

Increased global warming is posing a major threat to global environment. The buildings and industries are the large emitters of carbon dioxide emissions, the major greenhouse gas, and accounting for about 78% of the world's annual coal consumption, 41% of the world's electricity use, 35% of the world's natural gas consumption, and 9% of global oil consumption. According to McKane (2007), developing countries with emerging and expanding industrial infrastructure have a particular opportunity to increase their competitiveness by applying energy efficient best practices. Meanwhile increased globalization and the opening up of domestic markets will make the implementation of cost-efficient energy efficiency measures within industry even more necessary (Rohdin *et al*., 2006).

As explained by Hrustic *et al.,* (2011), focusing on a reducing energy end-use at the company is one of major ways to overcome this energy crisis. Energy Management System (EnMS) is such tool which supports companies in this important work. Among the available EnMSs in world, ISO 50001- energy management system (EnMS) is the most popular standard to date. Though ISO 50001 is being implemented all over the world, it has not yet been developed exclusively in Sri Lanka. Even though ISO 50001 is gaining recognition as an internationally adoptable energy management system, at present there are only a handful of ISO 50001 accredited buildings in the country (Senaweera, 2011). This implies that there may be some resistance, barrier or other reason which prevents the implementation of ISO 50001-EnMS in Sri Lanka. If such issues prevail, they may have arisen due to several unidentified causes. Hence, the adoptability of ISO 50001 in Sri Lanka is a questionable area

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that has not yet been explored. Therefore, a need was identified to explore the adoptability of ISO 50001- EnMS in the Sri Lankan context to recognize the feasible and appropriate means of achieving energy efficiency in buildings

This study therefore, aimed at finding enablers and barriers for the implementation of ISO 50001 - Energy Management through a comprehensive literature survey and unstructured expert surveys.The paper structure begins with a review on Sri Lankan energy crisis and building energy consumption followed by a literature review on identifying enablers and barriers of establishing national energy management system (EnMS) and need for implementing of ISO 50001- EnMS within the Sri Lankan context. Finally it presents the discussion of research findings together with future research agenda.

2. GLOBAL ENERGY CRISIS

Rapidly growing world energy usage has already elevated the concerns regarding supply difficulties, reduction of energy resources and major environmental impacts (Lombard *et al.*, 2008, pp. 394-398). Therefore, there is probably no severe topic more in the public concern now than energy. In the ISO Focus (2009) magazine, Edwin Pinero has highlighted the current energy crisis situation as an overriding concern in the minds of citizens, politicians, and businesses. Hence, energy touches all aspects of society and the effects of shortages can reverberate throughout economies and the daily lives of entire population.

The principal business of an industrial facility is making a profit through production of goods and services, not ensuring energy efficiency. However, the cost of energy is one of the main cost drivers for businesses and therefore, reduction in energy consumption leads to reduction in operating costs, and thereby helps to improve the profitability of organisations (Jayamaha, 2006). As explained by McKane (2007), in developing countries, the portion of the energy supply (excluding transport) required for buildings is frequently in excess of 50% and can create problems between economic development goals and a constrained energy supply. Especially in Asian countries, the absolute figure is rising fast due to construction booms and technology developments (Lombard *et al*., 2008).

To overcome this problem and be effective, energy efficiency programmes need to be engaged in the industry at the management level as well as at the operational level. However, energy savings potential is intensely fixed in industrial operational and management practices (McKane, 2007). Therefore energy efficiency, "using less energy to provide the same service" (Lawrence Berkeley national laboratory, 2013, para.1) should be achieved as a corporate goal of the entire organisation. The process of achieving energy efficiency can be identified as the energy management that supports the three pillars of sustainability: economy, environment and society (Piñero, 2011).

3. ENERGY MANAGEMENT SYSTEMS (ENMSS)

According to the Wongtharua *et al*., (2005), energy management can be defined as managing all kinds of energy used in an organisation by creating an optimum programme of purchasing, generating and consuming various types of energy based on overall short-term and long-term management programmes, with due consideration of costs, availability, economic factors, and so on. Furthermore, Piñero (2011) has identified well-organized tools, guidance, and resources; as the key requirements of energy management. These tools, guidance, and resources should include basic information on how to integrate energy management into the overall organisational management structure.

Energy management system standard provides guidance for industrial and commercial facilities to integrate energy efficiency into their management practices, including fine-tuning production processes and improving the energy efficiency of industrial systems (Sri Lanka Standard Institute, 2013). By identifying the importance of managing energy and the necessity of such system, the Environmental Energy Technologies Division, USA has defined well planned EnMS as an international framework for industrial, commercial, or institutional facilities, or entire companies, to manage their energy, including procurement and use. Further, many countries including Denmark (DS

2403 E:2001), Sweden (SS 627750:2003), Ireland (IS 393:2005), Korea (KSA 400:2007), Spain (UNE 216301:2007), China (GB/T 23331:2009), U.S.A. (ANSI/MSE 2000: 2000) and the European Union (EN 160001:2009) have developed national EnMSs to integrate energy efficiency into their management practices while fine-tuning operating processes and improving efficiency of industrial systems used in buildings (Senaweera, 2011).

Though there are several countries and regions that have developed and are developing various energy management standards on the international front, they have subtle variations in language, content, and approach which make them unsuitable to be applied internationally. Therefore the International Organisation of Standardization (ISO) identified energy management; as one of its the top five priorities based on its enormous potential to save energy, increase profitability, and reduce greenhouse gas (GHG) emissions worldwide (McKane, 2009) and took the initiative to fill the above requirement by developing ISO 50001-EnMS which can be globally applied.

4. ISO 50001 Standards on Energy Management Systems: An Overview

ISO is the International Organization for Standardization. It has a membership of some 160 national standards bodies from countries large and small, industrialized, developing and in transition, in all regions of the world. ISO's portfolio of over 18 600 standards provide business, government and society with practical tools for all three dimensions of sustainable development: economic, environmental and social (International Organisation for Standardization, 2011).

ISO 50001 is an international energy management standard that provides a framework around people, information systems and technology to deliver sustained year on year energy and carbon savings. ISO 50001-EnMS requirements with direction to use, was published in June 2011. It provides a framework for industrial plants, commercial facilities or whole organizations to manage energy. In accordance with ISO, the standard could affect up to 60% of the world's energy use, with wide applicability across national economic sectors (Sri Lanka Standard Institute, 2013). This standard has developed with the partnership of ISO members for the United States (American National Standards Institute - ANSI) and Brazil (Associação Brasileira de Normas Técnicas - ABNT) under the participation of 12 observers and liaison organizations include the United Nations Industrial Development Organization (UNIDO) and the World Energy Council (WEC) (Senaweera, 2011).

ISO 50001 has been able to draw on numerous national or regional energy management standards, specifications, and regulations (International Organisation for Standardization, 2011). Noteworthy is the fact that it has provided stimulus and a framework for the development of national standards, policies, laws and regulations. This will be especially true in developing countries and emerging economies that still lack national energy management standards (McKane, 2009). Also ISO 50001 will provide organisations and companies with technical and management strategies to increase energy efficiency, reduce costs, and improve environmental performance (Sri Lanka Standard Institute, 2013). Moreover, organisations can integrate ISO 50001 with other management systems such as quality, environment, occupational health, and safety.

The Director General of Sri Lanka Standards Institute (SLSI), who are the regulatory body and member body of ISO, has the right to adopt this standard as a national standard. SLSI has planned out a series of steps to promote this standard throughout the country with the support of the Sri Lanka Sustainable Energy Authority (SLSEA). They have a wealth of experience in certifying management systems as they have certified over 500 organisations in Sri Lanka and overseas on different management systems such as ISO 9001, ISO 14001, ISO 22000, and ISO 18000 (Senaweera, 2011). SLSI has confirmed that the purpose of ISO 50001 is to enable organisations to establish necessary system and processes for enhancing the energy performance, energy efficiency and energy consumption. Furthermore this system standard helps to overcome environmental impact and cost related problems through systematic management process (Senaweera, 2011). Moreover, the standard provides various benefits such as providing significant financial savings by systematic improvement in energy efficiency, protecting against future energy price rises, supporting continual improvement, reducing carbon and other emissions, compliance with legal and regulatory requirements, providing framework for global best practice in energy management, providing global recognition demonstrating credible green credentials, providing continuity and momentum when changes in key staff occur and easily integrating into other Management Standards such as ISO 9001, ISO 14001 and ISO 18001.

Organisations can develop and implement an energy policy, objectives, targets and action plans based on legal requirements and information of significant energy use. ISO 50001 also explains how to demonstrate competence, operational control and best practice procurement of energy services, products and equipment. This international standard is based on the Plan – Do – Check – Act (PDCA) continual improvement framework and incorporates energy management into everyday organizational practices, as shown in Figure 1.

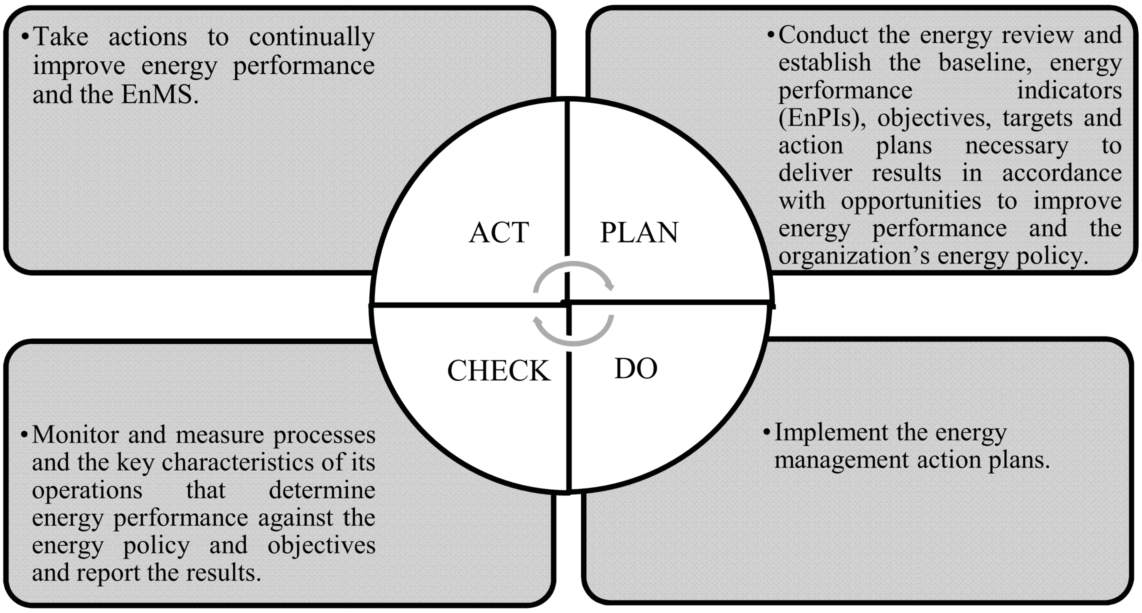

Figure 1: PDCA Cycle of ISO 50001 Implementation Procedure
(Source: Adapted from SLS ISO 50001:2011, 2013)

It is hoped that the introduction of ISO 50001 will result in widespread uptake of the standard among all types of energy users. The Plan-Do-Check-Act model has been proven successful for managing quality and environmental issues (ISO 9001 and ISO 14001). Therefore, this may provide great support to the owners, facilities managers and users of buildings, of Sri Lanka whilst contributing to improve the national economy. Each new management system standard is an improvement over the prior ones based on lessons learned from the experiences of the forerunners. Therefore, the driver of a successful energy management system will not only lead to effective management of the process, but also increased energy efficiency and more prudent energy use (Piñero, 2011).

5. RESEARCH METHODOLOGY

The study was structured to be conducted in three stages. The arrangement was effective due to the nature of problem being studying. The first two steps, literature review and desk study identified a list of enablers and barriers available for the implementation of ISO 50001. As the final step, an expert survey was carried out with professionals of SLSI, who is the responsible party for regulating ISO standards within Sri Lanka. The professionals selected for the preliminary survey have expertise knowledge and experience in auditing and implementation processes of ISO 50001of SLSI. The data collection was mainly carried out through unstructured interviews. The purpose of conducting an expert survey was to get the comments of the experts who were interviewed and refine the list of enablers and barriers identified after the desk study to comply with the Sri Lankan context.

6. ENABLERS AND BARRIERS OF IMPLEMENTING ISO 50001 IN SRI LANKA

A comprehensive literature survey and desk study was first carried out to identify the enablers and barriers for the implementation of ISO 50001. The findings of the review are given in Table 1. The enablers and barriers were derived based on scientific literature (Rohdin *et al*, 2006; Piñero, 2011; Hrustic *et al.*, 2011; Chayapoosorn and Ngaoprasertwong, 2012; ISO, 2013; McKane, 2009).

Table 1: Identified Enablers and Barriers for Implementing ISO 50001: Literature Findings

Enablers	Barriers	
Internal and external recognition and rewards (United State Environmental Protection Agency)	Institutional problems (MacKane *et al*., 2009 and Thollander and Dotzauer, 2010)	Low credibility and trust on information
Reduce cost (SLS ISO 50001:2011, 2013)		Weak principal agent relationships
Engage top management (ISO Focus^{+}, 2011)		Lack of support and guidance
Reduce environmental impact (GHG emission). (Lambert, 2011)	Financial constraints (Rohdin *et al*., 2006)	Unbearable certification cost
Innovative, flexible and scalable (SLS ISO 50001:2011, 2013)		Hidden costs Difficulties on budget allocation
	Complexity of certifying processes	Large amount of documentation required Availability of highly technical sections Time consuming procedures for achieving the accreditation
	Organizational cultural aspects (Rohdin *et al*., 2006)	Lack of power on energy management Negative attitudes of employees
	Unawareness on the importance of applicability (Siriwardana, 2009).	

As the next step, an expert survey was conducted with the professionals from the SLSI, who have the expertise knowledge on the subject of energy management as well as the implementation of ISO 50001 standards. The identified enablers and barriers through the desk study were evaluated and refined in accordance with the Sri Lankan context. Table 2 provides the list of enables and barriers which were identified through the expert survey.

Table 2: Identified Enablers and Barriers for Implementing ISO 50001: Expert Survey Findings

Enablers	Barriers
Formalized and documented energy policy and objectives	Insufficient benefits and outcomes
Regulatory compliances	Lack of support and guidance
Improve business performances	Inconsistency on top management support
Integrate the management system	
Secure energy supply	

The Table 3 provides the refined list of enablers and barriers of implementing ISO 50001 in Sri Lanka, which fulfills the final objective of this paper.

Table 3: Enablers and Barriers for Implementing ISO 50001in Sri Lanka

Enablers	Barriers	
Internal and external recognition and rewards	Institutional problems	Low credibility and trust on information
Formalized and documented energy policy and objectives		Weak principal agent relationships
Regulatory compliances		Lack of support and guidance
Improve business performances	Financial constraints	Unbearable certification cost
Reduce cost		Hidden costs
Engage top management		Difficulties on budget allocation
Reduce GHG emission	Complexity of certifying processes	Large amount of documentation required
Integrate the management system		Availability of highly technical sections
Secure energy supply		Time consuming procedures for achieving the accreditation
Innovative, flexible and scalable	Organizational cultural aspects	Lack of power on energy management
		Negative attitudes of employees
	Unawareness on the importance of applicability	
	Insufficient benefits and outcomes	
	Lack of support and guidance	
	Inconsistency on top management support	

Following section provides descriptive information relating to the commonly available enablers and barriers for implementation of ISO 50001 EnMSs, in Sri Lanka.

6.1. Enablers of Implementing ISO 50001 in Sri Lanka

Followings are the main enablers that could be identified through the literature review together with the views of professionals of SLSI.

6.1.1. Internal and External Recognition and Rewards

Recognizing the contributions of teams and individuals helps to reinforce the value of energy efficiency and encourage even greater improvements. Acknowledging successes will help sustain motivation. Verbal appreciation, simple forms of thanks like formal written commendations and certificates, plaques presented at award ceremonies, salary increases, and stock options can all act as enablers.

External recognition from a third party (government agencies, non profits, the media, and trade associations) validates the importance of the energy program, provides satisfaction to those who earned the award, and enhances the organization’s public image. A solid reputation contributes to the organization’s competitive advantage by making it more attractive to customers, current and potential employees, lenders, and business partners.

6.1.2. Formalized and Documented Energy Policy and Objectives

Though technology has been continuously developed, documentation procedure has gained significant importance over any other business operation. Therefore, maintaining well documented procedures has become an enabler for its users. Proper documentation procedures of ISO 50001 have made it easier to follow by organizations, itself. This has improved the user friendly aspects of the EnMS. Also documentation is important for decision making purposes and ensuring the better operations of the entire system (Sri Lanka Standard Institute, 2013).

6.1.3. Regulatory Compliances

Implementation of ISO 50001 intended to reduce greenhouse gas emissions and other related environmental impacts and energy cost through systematic management of energy. Therefore ISO 50001 automatically fulfils regulatory requirements of organisations. Noteworthy as a country without proper regulations relating to energy management of buildings, this can take as the base for developing the energy related regulatory requirements (Sri Lanka Standard Institute, 2013).

6.1.4. Improve Business Performances

Drive greater productivity by identifying technical point solutions and affecting behavioral change to reduce energy consumption. By minimizing unnecessary energy wastages and identifying high technological solutions for existing operation can leads organizations towards fully productive future (Sri Lanka Standard Institute, 2013).

6.1.5. Reduce cost

Reduce energy cost via a structured approach to identifying, measuring and managing organizational energy consumption (Sri Lanka Standard Institute, 2013).

6.1.6. Engage Top management

Top management will consider energy management a key business issue. This leads to increase the capital allocations on energy management, consideration and support on implementing ISO 50001(Sri Lanka Standard Institute, 2013).

6.1.7. Reduce GHG Emission

This is a significant enabler to meet stakeholder expectations or obligations now and in the future. Also this may relates to impacts of the organizational operations towards the environment (Sri Lanka Standard Institute, 2013).

6.1.8. Integrate the Management System

Align organizational EnMSs with existing management systems for incremental benefits (Sri Lanka Standard Institute, 2013).

6.1.9. Secure Energy Supply

Implementation of ISO 50001 within an organization helps to understand the risk exposure and identify the areas of organization at great risk. Availability of well managed energy supply system is an enabler for organizations (Sri Lanka Standard Institute, 2013).

6.1.10. INNOVATIVE, FLEXIBLE AND SCALABLE

Develop opportunities for new products and services in the low-carbon economy of the future. Also it is applicable to any organization, large or small and from any industry (Sri Lanka Standard Institute, 2013).

6.2. BARRIERS OF IMPLEMENTING ISO 50001 IN SRI LANKA

According to SLSI, most probably, implementing an EnMS is considered as a burden for their existing operations by most of the organizations within the developing countries like Sri Lanka. Instead of seeing at the business opportunities for increasing sales and cost reductions through ISO 50001, they only concern it as a threat for their market competitiveness. Therefore, barriers for implementation must be acknowledged and addressed to minimize them for avoiding the unnecessary difficulties appear in different stages of implementation. Followings are the significant barriers identified through desk studies of the ISO, U.S. Environmental Protection Agency, Edwin Piñero *Chairman of ISO PC 242*, and U.S. Environmental Energy Technologies Division.

6.2.1. INSTITUTIONAL PROBLEMS

These institutions can be identified as the accredited certification bodies for ISO 50001. Thollander and Dotzauer (2010) have identified absence of market for best available technologies and lack of technical knowledge and required human resources, lack of experts relating to EnMSs and lack of energy policy as the critical issues for the implementation of energy management standard (MacKanel, 2009).

6.2.2. COMPLEXITY OF CERTIFYING PROCESSES

This is a major barrier that has identified through the ISO 50001 Energy Management Systems implementation case study at London South Bank University. According to that situation larger amount of documentations and over application of technical words has made the implementation procedure difficult. It consumes additional amount of human resources to handle the system.

6.2.3. ORGANIZATIONAL CULTURAL ASPECTS

Different organizational cultures, values and norms act as barriers for implementing ISO 50001 within particular organisations. Poor leadership and absence of dedicated energy coordinator is the main reason for this problem arises (Rohdin et al., 2006).

6.2.4. FINANCIAL CONSTRAINTS

Though this is very important for organisation, it must be feasible to purchase, implement and practice. Cost of implementation and cost of renewal are significantly acting as barriers for small and medium scale enterprises (SMEs) (Rohdin et al., 2006).

6.2.5. UNAWARENESS ON THE IMPORTANCE OF APPLICABILITY

ISO 50001 has introduced to Sri Lankan organisations on 2011. But it has not properly marketed within the country. Therefore most of the organisations are not properly attentive on this standard. According to SLSI, there are very few awareness programmes regarding ISO 50001 and no any training programmes on implementing, handling or auditing the standard (Siriwardana, 2009).

6.2.6. INSUFFICIENT BENEFITS AND OUTCOMES

This can be identified as the risk of investing in EnMS. For example, even though managers know what the capital cost is for an EnMS investment, uncertainty about the long-term savings in operating costs means the investment is a risk. Therefore unawareness on benefits and outcomes of implementation of ISO 50001 is a barrier.

6.2.7. Lack of Support and Guidance

Another barrier is not receiving enough level of information, lack of sources of information and support from the responsible parties regarding the implementation of ISO 50001. Lack of information, imperfect information and cost of information on energy management systems are the main reasons for this barrier.

6.2.8. Inconsistency on Top Management Support

It should be noted that in regard to energy management, an increased focus on core business, which has been a strong trend within management and organization since the beginning of the 1990s, may prevent successful adoption of energy management practices (Thollander and Ottosson, 2010)

7. Discussion and Future Research Agenda

Although energy seems a pervading subject, that all people have to deal with on a daily basis, research regarding this topic is scarce. Building energy efficiency is one of the most significant means of reducing the threat of increased global warming. During the last decade, energy prices rose significantly for the local industry. Mainly electricity prices and oil prices have almost doubled. Even more price increases are to be expected. Therefore, identifying opportunities available for going towards the energy management system can be considered as national requirement for Sri Lankans.

Implementation of ISO 50001 intended to lead to reductions in greenhouse gas emissions and other related environmental impacts and energy cost through systematic management of energy. There is less number of organisations which have obtained and applied to obtain the ISO 50001 system. The enablers and barriers of implementing an ISO 50001 EnMS in Sri Lanka have been identified through a comprehensive literature survey, desk study and an expert survey which were employed in achieving the aim of this article.

According to the finding internal and external recognition and rewards, formalized and documented energy policy and objectives, regulatory compliances and improve business performances have been identified as key enablers while institutional problems, complexity of certifying processes, organizational cultural aspects, financial constraints and unawareness on the importance of applicability had been identified as key barriers. At the next stages of this research, these results are planned to be used in developing the framework for implementing ISO 50001- Energy Management System within Sri Lanka.

This study highly focused on identifying enablers and barriers which affect the implementation of ISO 50001 – Energy Management System in Sri Lankan context.

The next step has planned with case studies which will be carried out based on buildings which have implemented ISO 50001 – Energy Management System. The future research agenda will consist of following objectives:

- Identify the major enablers and barriers in implementing ISO 50001 in Sri Lankan context
- Introduce suitable solutions to overcome those barriers of implementation
- Develop strategies to promote the enablers of implementing ISO 50001
- Develop a framework for adopting ISO 50001 in Sri Lankan context

This framework will be worthwhile for organizations that are following and willing to implement ISO 50001 – EnMS within their organizations effectively.

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E-TENDERING FRAMEWORK FOR PUBLIC PROCUREMENT IN SRI LANKA

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ABSTRACT

The growth of Information and Communication Technology (ICT) opens new opportunities for businesses all over the world which accelerates the competition among the businesses and professions. Even though good communication is an essential tool for procurement and consultation process, the usage of IT in public procurement in Sri Lankan construction industry is not as much of other sectors, while other developed and developing countries are practicing and gaining advantages. However, adopting e-Tendering in pre contract stage, yields several benefits which can be experienced directly and indirectly. In an economic point of view, e-Tendering enhances the efficiency through transaction cost savings and reduce the direct procurement costs, maintaining transparency, accountability, ease of use and speedy exchange of information including other intangible benefits such as reduced administrative costs. Eventually, e-Tendering will lead to pave the way to reduce the time, cost and resources of a project from which the triple bottom line of the Sustainability can be accomplished to a great extent. This research paper discusses the benefits and challenges in adopting e-Tendering and the legal, technological and material requirements to be appraised in forming a proper framework for e-Tendering. A qualitative research approach is proposed considering the aim and the context of the study.

Keywords: *Construction; e-Tendering; Public Procurement; Sri Lanka; Technology.*

1. INTRODUCTION

Tendering is probably the most critical and important activity in a construction project life cycle. Inefficient outcomes of a tender action will significantly affect the project success. However, very rarely a tender action is done without a rush. As a result, the decisions often become less than optimal. Advancements in Information and Communication Technologies (ICT) has been identified and effectively used to face these challenges for many years. However, this is not the case of Sri Lankan construction industry. e-Tendering, the key solution known to improve the efficiency of tendering by using ICT, is not practiced. A research was initiated to explore the key functions and requisites of tendering process in order to recommend a suitable e-Tendering Framework for construction. The research is an ongoing study and this paper presents the initial literature findings together with proposed research methodology.

2. CONSTRUCTION PROCUREMENT

Construction industry as an open system, which is very sensitive to change; its characterization throughout the world is determined by the operating external environment and consists of subsystems such as economic, political, financial, legal and technological systems (Rameesdeen, 2002). This has led 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 industries in the world are striving to tackle these changes through the new and innovative ways of construction, efficient resource utilization and better organization of projects. It is inevitable that, when concerning about proper utilization and efficiency, construction procurement has the vital role to be considered.

The construction procurement system can be defined as an amalgam of activities undertaken by a client in order to obtain a new building and includes processes that seek to place risks and obligations

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on the various parties to the project (Ross, 2005). Moreover, Naduranga (2012) clarified that, in traditional procurement there are five steps to be followed to complete the procurement process. These are shown in Figure 1. The process starts with the requirements for an item or a service and ends after the settlement of payments to the supplier.

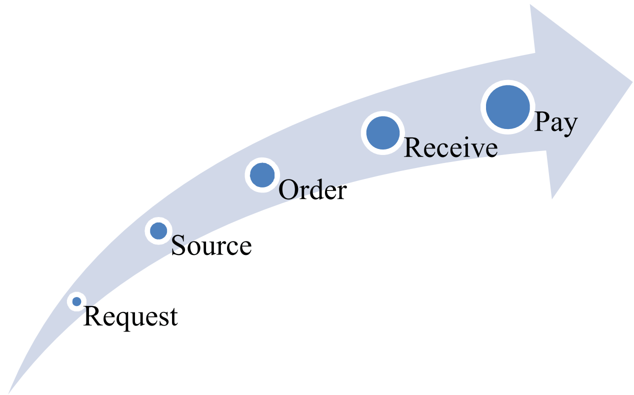

Figure 1: Process of Traditional Procurement (Source: Naduranga, 2012, p 09)

The steps of the procurement process are substantiated by Luis (1999) elaborating that, the term Procurement Process is used to describe the process required to supply equipment, materials and other resources required to carry out a project. This process usually involves sub-processes such as acquisition, purchasing, logistics, monitoring, quality assurance and contract administration. Sumasekara (1997) through his research clarified that the procurement method depends on the client's requirements and the contractor's proposal. Moreover Sumasekara (1997) categorized the available procurement methods as traditional procurement system, Design and build, Management contracting, Construction management.

3. CONCEPT OF E-PROCUREMENT

A broadly-based evolutionary development of electronic business has set in across the globe. This development, though not visibly revolutionary in character, has been nonetheless powerful in its impact, and the maturity of e-business has substantially increased across sectors and regions (European Commission, 2012), which conveys the idea of promotion of sustainable use of energy. Furthermore according to Eddie (2011), e-Procurement (a sector within e-business) has further been promoted as a means of producing cost savings through even a minor uptake in adoption within the construction sector.

Sumasekara (1997) has shaped out the current procedure in the public procurement system as Project Strategy, Prequalification, Obtaining Tenders, Evaluation of Tenders, and Award of Contract. This method is used by the Corsi (2006) to develop the concept of e-procurement and e-Tendering. The Figure 2 demonstrates the steps to be followed during the e-procurement process.

4. TENDERING PHASE

Lou (2009) argued that, the tendering phase is deemed to be the most critical and important throughout the lifecycle of the construction project. This phase will shape the contractual and legislative agreements between the client, consultant team, contractor and other members of the project. Based on traditional contracting, the tendering phase starts when the drawings and tender documents are completed. Compilation and analysis of project data are gathered through the stages of strategic briefing, outline and final proposals, production information, statutory approvals, building contracts and others. This phase is information-intensive and paperwork-heavy. Tender documents comprise of the invitation to tender, form of tender, architectural drawings, bills of quantities, health and safety agreements and others. These documents are paper intensive, not portable, expensive, tedious and troublesome to produce. Once the tender documentation is prepared, it is ready to be distributed to interested bidders. To reduce this material usage and time wastage the concept of e-Tendering is emerging among the construction professionals.

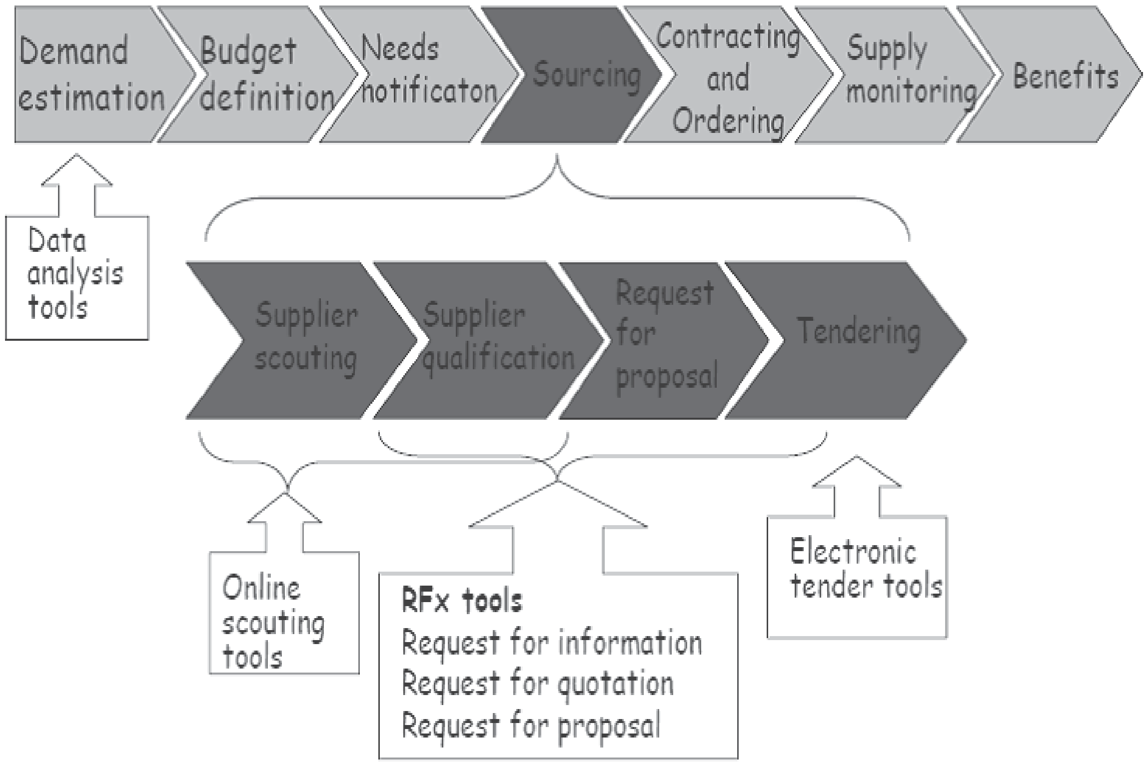

Figure 2: Process of e-Procurement (Source: Corsi, 2006, p 05)

5. INTRODUCTION TO E-TENDERING

Black *et al.* (2005, as cited in Oyediran, 2011) detailed that e-Tendering is basically an expression used to describe the dissemination and receipt of tender information, indication of interest in tendering, receipt of tender documents, submission of tender sum and final selection of successful tender for contracts via the internet. It does not change the basic principles of tendering, just the method of exchange of documents and information (RICS, n.d). Furthermore CIPS (2006) describes it in more detail e-Tendering portals (secure dedicated websites, specifically set up for the exchange of information and tender documents electronically over the internet) and systems should allow the buyer to create, manage and transmit contract announcements (notices and addenda) electronically. Tenderers can create and manage multiple profiles containing expressions of interest/pre-qualification information. Invitation to Tender (ITT) documents can be exchanged electronically, and the assessment and award of tenders are usually automatic. Dean *et al.* (2006) gave a conservative idea of illustrating even though there are a number of e-tender systems available to governments and the construction industry each of the systems generally offers similar communication tools (such as messaging to all parties), document management tools and audit trails. The functionality and process aspects of current e-tendering systems are similar and attempt, at most points, to mirror the legal requirements of a paper tendering system. The main parties in an e-Tendering system are the principal and the Tenderers.

6. INFLUENCES TO e-TENDERING

6.1. *ORGANIZATIONAL INFLUENCE*

When new software or new processes are introduced in any organization, it is only natural for the employees to be cautious and afraid of their jobs; employees will fear responsibility and process changes (Lou, 2006 cited Lou, 2009). The main reasons for the high percentage of systems failure is the rarely purely technical in origin. They are more related to the organizational "soft issues", which underpin the capability of the organization to successfully absorb information systems (IS) and Information Technology (IT) into its work practices; in this context one or more collaborative environment. IT is still, in many cases, being considered by the management of organizations as a cost-cutting (Alshawi, 2007 cited Lou, 2009). People are the determinant force in deciding the success or failure of the uptake of e-Tendering and collaborative environments. When the individual is willing to change, there will be the willingness and aspiration to explore new horizons. Top management support, the presence of an innovation champion among employees and a motivated manager will drive the desire to try and change from the old ways Neef *et al.* (2001) as mentioned in Lou (2009).

The main tasks of e-tendering flat form are identified by Netcoach (n.d) as follows;

- Publication of the tender (i.e. full text of the tender)
- Degree of research involved in compiling the project (meant for tender) the various criteria used (market segment, trades, products/services, regions, time to implement etc.) and full text research.
- Easy exchange of digital files, with the help of data in an agreed data format
- Administration of the awarding process (user and document administration, current services.)
- Handling the legality of awarding, through signatures / encryption and time

6.2. *GOVERNMENT INFLUENCE*

Tendering processes are considered to be a suitable mechanism for governments to fairly assign contracts for construction projects and procurement. The demand for efficiencies to be created in the process has resulted in a significant number of governments implementing e-Tendering systems (Dean, 2006). Government (often key client within the construction industry) and with its increased tendency to transact its business electronically, undoubtedly has an effect on how various private industry consultants contractors, suppliers and related parties do business by offering a wide range of (current and anticipated) E facilities or services including e-Tendering. Overall going business electronically is found to have a profound impact on the way today's construction business operate-streamlining existing processes, with the growth in innovative tools , such as tender, offering the construction industry new responsibilities and opportunities for all parties involved. It is therefore important that these opportunities should be accessible to as many construction industry businesses as possible (Eddie, 2010).

Kajewski and Weippert (2004) categorized the governments' main expectations of implementing E-Tendering as, best value for taxpayers' money and increased efficiency and effectiveness. However, they further put forward the consistent tendering practice across Government, promotes overall e-Commerce initiative and environmentally friendly due to a predominantly 'paperless' process as added expectations of the government when implementing E-tendering.

6.3. *LEGAL INFLUENCE*

According to Islamy (2002) there is a need to ensure that, the users' online privacy is protected, both legally and technologically as this assurance will make them feel comfortable to surf the internet and more importantly to submit their data and spend their money online. The researcher added that the legislation is important due to no matter how advanced the technology may be, without any legislation that regulates the rights and duties the technology can be abused (Yusoff, 2011). Many governments are increasingly relying on board range of resources outside the traditional governmental law enforcement expertise to address Cyber threats and forensic issues. As such new institutional models may have to be created. The Sri Lankan experience is as interesting example. In mild 2006 Sri Lanka CERT (Computer Emergency Response Team) was created to address cyber security incidents. This is a government owned company (A subsidiary of ICT Agency of Sri Lanka – ICTA), established and runs with highly skilled incident handlers where the board consists of a range of key stakeholders such as enforcement authorities, bankers, private sector and academia (Fernando, 2009).

6.4. TECHNOLOGICAL INFLUENCE

The Internet provides considerable opportunities for firms to streamline their business operations, as well as offers greater choices and lower prices to customers. A large number of enterprises have migrated to Internet-based systems for increased efficiencies, lower costs, and the ability to operate in real time across different platforms. E-commerce is changing business economics and as a result, many firms are reengineering their core business processes (Netcoach, n.d). As in the Prior to Tenderer Communication stage, the integrity and confidentiality of most network communications must be maintained. In closed or restricted tenders all communication can be kept confidential using Secure Sockets Layer (SSL) an effective mechanism to provide integrity and confidentiality for communications or other cryptographic mechanisms. Secure communications protocols such as SSL only protect data during transmission. In addition to communications security, it is advisable to encrypt sensitive tender documents, such as offers, while stored. The main improvement of the Tender Submission and Two-Way Communication stage is that tenderers can upload electronic tender submission documents. Hyper Text Transfer Protocol (HTTP)

file upload or similar point to point, connection oriented protocol should be used rather than email or other store and forward protocols especially when information is not encrypted. This ensures that non-trusted intermediate parties cannot store data for extended periods of time before being sent to the electronic tender box. Security mechanisms that simulate the physical tender box must ensure that electronic tender documents cannot be opened before the designated opening time in the tender conditions. The tender box simulation security may be considered equivalent to the current common practice of using a physical tender box that requires two keys to be opened. One approach to simulate this system is to open the electronic tender box using threshold public-key decryption. This encryption system requires multiple cryptographic keys to be used to decrypt an encrypted message (Dean, 2006).

7. BENEFITS OF e-TENDERING

The primary benefit that, government agencies, service providers, and industry seek to achieve from implementing electronic procurement (e.g. e-Tender) is to reduce the liable cost of business and to deliver services that are more efficient for the community. e-Tendering is a key strategy in the development of various electronic procurement programs and initiatives, offering additional opportunities for industrial businesses, contributing to a globally competitive economy, and helping secure a sustained economic growth. (Kajewski and Weippert, 2004)

In the opinion of the objective of e-Tendering is to specifically increase productivity during the tendering process by decreasing paper handling and speeding up communication and interaction. This represents the ultimate goal of E-tendering, a shift from manual paper methods to fully electronically enabled means of communication. One of the major strengths of arguments for e-Tendering is the remote accessibility of the system. Thus making it possible for a tender manager, tenderer, contractor or client to access the facilities of the tender engine from anywhere in the world without being impeded by geographical location constraints (Seah, 2004 cited Oyediran 2011). Sell's 2005, study (as cited in Lavelle 2009, p105) explains how time and cost savings can be gained. Avoiding the postal system leads to possible reductions in the tender period or use of previously abortive time to concentrate on the production of the tender. Printing costs will drop, as well as copying and postage costs, together with the associated staff time and overhead costs. Kajewski and Weippert (2004) structured the general benefits as follows.

- Streamlines the whole tendering process.
- Provides improved and secure access to tender information.
- Brings about innovative business processes.
- Initiates greater opportunities for small and regionally based businesses.
- Allows downloading of electronically submitted tenders in a form suitable for evaluation purposes without having to manually re-enter data.
- Makes it easier for businesses to obtain tender documentation and to submit.

8. LIMITATIONS TO E-TENDERING

A list of barriers ranked by study of Eddie *et al.* (2007) highlighted that, uncertainty as to the legal position of e-procurement is the major barrier to the implementation of e-tendering. Simultaneously the argument goes that, company culture and upper management support will highly influence the implementation. Not having the IT infrastructure, expensive IT systems, lack of technical expertise, lack of E-procurement knowledge / skilled personnel, lack of business relationship with suppliers providing E-procurement and Security of transactions are the added limitations of the implementation. Carayannis *et al*. (2005) approved the above findings. Their research stated that, public procurement faces many deficiencies. They enumerated these as complicated procedures and extended relationships, excessive state intervention, absence of a clear national IT policy, lack of flexible centralized control, lack of information quality and resistance to change. With the exception of a reduction in paper in public procurement each of the above remain as barriers to implementation of a system of. However, it is pointed out that "resistance to change" is one of the biggest barriers to the introduction of e-Tendering within the public sector. Resistance to change, lack of a widely accepted solution and lack of leadership seem to be major barriers. Therefore, a cultural change needs to take place prior to adoption of an e-Tendering system. This is proved by the Martin's 2008 findings (cited Eddie *et al.,* 2010, p. 24) based on the United Kingdoms' construction industry, the perceived advantages of monitory savings and efficiency gains prompted the UK government to set targets for all procurement activities to be fully electronic by the end of 2005 (Local E-Gov, 2004 cited Eddie *et al*., 2010). Martin (2003 cited Eddie *et al.,* 2010) had shown that only 2.9% of Contract Documentation was being transmitted and received in Construction Industry Trading Electronically (CITE) format. Five years later, Martin (2008, cited Eddie *et al.*, 2010) shows that less than 20% of tender documentation is sent out and received through e-tendering.

Security is a major concern when working on the internet. Jennings (2001, cited Eddie *et al*., 2007, p.111) states "The World Wide Web leaks like a sieve. Data transmitted on it can be garbled, can reassemble wrongly at the other end, or can display only partially because of incompatible software". Many of the banks although acknowledging these problems, have set systems in place to mitigate these problems.

9. RESEARCH METHODOLOGY

Development of e-Tendering framework for government projects requires identification of both regulatory and practical requisites of a tendering process. A suitable research methodology has to be developed to fulfil this need.

9.1. RESEARCH APPROACH

As explained by Yin (2009), a research approach is the way of collecting and analyzing empirical evidence, following its own logic having its on advantages and disadvantages. Qualitative and quantitative research approaches are the two main schools of research design. Quantitative approach tend to relate to positivism and seek to gather factual data and to study relationships between facts and how such facts and relationships accord with theories and the findings of any research executed previously (Pinsonneault and Kraemer, 2002). Survey researches and experimental researches generally come under quantitative approaches. By using a qualitative approach the researcher will study whole population as individuals or groups and could be able to identify beliefs, understandings, opinions and views of people (Fellows and Lui, 2003). Case study research, ethnography, action research and grounded theory approach can be taken under qualitative approaches.

9.2. TECHNIQUES FOR DATA COLLECTION

This section is focused on determining how the qualitative data would be collected. As described by Yin (2003), there are six sources of data collection techniques including documents, archival records, interviews, direct observation, participant observation and physical artefacts.

Documentary survey (Secondary data)

The intention of documentary survey is to identify the important data on e-Tendering in global context and in Sri Lanka, critical issues in implementing e-Tendering as a sub part of public procurement method.

Interviews (Primary data)

The semi-structured interviews will be adopted as the data collection technique in this study because it offers sufficient flexibility to approach different respondents differently while still covering the same areas of data collection. The interviews will be carried out with professionals or who are involved in public procurement.

9.3. TECHNIQUES FOR DATA ANALYSIS

Content analysis, which is a technique of analysing data, involves codifying qualitative information into pre-defined categories, in order to derive patterns in the presentation and reporting of information. After gathering data from semi structured interviews, data reduction and concept identification will be done.

10. CONCLUSIONS

The construction industry is information sensitive and categorized as one of the most important industry in a developing country like Sir Lanka. e-Tendering solutions can undoubtedly improve the tendering process and drastically cut-down the amount of time taken. This can result in an increase in the amount of tenders undertaken at any one time and an improvement in the overall control of the process. End users can be given access rights to involve them in the process to a large work with purchasing to achieve the best overall value in terms of price and quality. The security policies have to be drawn up with the consideration of both the tendering business and its legal obligations, to ensure the designed system can generate legally admissible evidence. The security mechanisms have to be carefully integrated into the system to provide desirable security service for the complex contract processes involved in an e-tendering system. The transition towards full is not primarily a technical nor a technological challenge. It is above all an economic and political challenge, which cannot be overcome without strong commitment at the highest political level. While the study demands for objective conclusions, a quantitative approach will not offer deeper understanding about the Sri Lankan context. A qualitative research approach is proposed for the next step of the research.

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FACTORS AFFECTING ENVIRONMENTAL HEALTH AND SAFETY IN HEALTHCARE SECTOR

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ABSTRACT

Environmental Health and Safety (EHS) is a discipline, which involves creating a culture of health, safety, and environmental protection in a workplace. It provides workplaces that are injury-free and incident-free for all employees, visitors and contractors, as well as enhances the wellbeing of those parties and local communities. Therefore, EHS has a direct impact on morale of stakeholders, employee productivity as well as on organisational performance. Healthcare facilities are specific from others, and customers and workers in healthcare sector are exposed to huge amount of harmful contaminants compared to other working environments. There are many EHS issues that can be identified in healthcare sector, and inability to control such issues will become an epidemic to the whole society. Various factors determine the EHS condition of an organisation such as ventilation, lighting levels, noise, and design of workstations, safety measures in emergencies, to name few. Having a better understanding on those factors will enable the maintenance of effective EHS practices so that the negative impact of poor EHS practices can be minimized. Hence, the financial goals and objectives of the organisation can be achieved. Even though, such importance is there, studies on EHS is hardly found and a less attention has received to this subject. Therefore, the aim of this paper is to critically evaluate the factors affecting EHS in healthcare facilities. A comprehensive literature review was carried out to identify the EHS factors. Five environmental factors and eight occupational health and safety related factors were identified through the review and they be used to study the critical factors affecting EHS of healthcare facilities in future research agenda.

Keywords: *Environmental Health and Safety (EHS), Environmental Health and Safety Factor; Healthcare Facilities.*

1. INTRODUCTION

The concept of the safety of employees goes back to the start of the industrial revolution in Britain. However, with the scale-up of plant sizes in the 1950s and 1960s, new safety concerns were recognized and it was not only the slips, trips, falls and similar events, but also the processes and events (Ashton and Crawley, 2002). Further, it was recognised that occupational health and safety issues and the working environment have become linked to environmental issues and a proper Environmental Health and Safety (EHS) conditions provides workplaces that are injury-free and incident-free for all employees, visitors and contractors and enhances the well-being of its employees and local communities. Thus, the Environmental Health and Safety (EHS), was identified as a discipline which should be given a special attention.

Managing and implementing proper EHS strategies lead to achieve business objectives and improve the productivity of organisations. Though the occupational safety and health has become popular in the industry, managing impacts of the environment, safety and health of the customer as well as workers has received a little attention. However, identification of EHS factors and their effect on organisations' operations and stakeholders helps to take preventive measure and minimise the negative effects. Especially this is very much important for healthcare sector in which a huge amount of EHS issues can be found. Though such study is needed, a research which specifically addresses the EHS factors in healthcare sector is hardly found. Therefore, this paper aims at identify the EHS factors in

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health care sector.

The paper structure begins with EHS issues and followed by a literature review on identifying factors affecting to the EHS in healthcare environment within the Sri Lankan context. Finally it presents the discussion of research findings together with future research agenda.

2. ENVIRONMENTAL HEALTH AND SAFETY

According to the World Health Organisation (2013), environmental health is defined as physical, chemical and biological aspects of the human health and diseases that are determined by factors in the environment. It also refers to the theory and practice of assessing and controlling factors in the environment that can potentially affect human health. In addition, it includes ensuring that the surrounding environment, including work areas, laboratories or facilities, are free of dangers that could cause harm to a person working in those areas. A safe place to work is the key element of environmental safety. EHS together optimise the health and safety of the occupants while controlling the impacts of the environment. Further, as Stevens (2010) mentioned, the practicable EHS minimizes the negative impact of an organization's operations, activities, products and services on environment.

Early in 20th century in the industrialized countries, occupational health and safety was often driven by a simplistic focus on control the protection of the workers from exposure to health and safety risks. Special emphasis was given to engineering control and protective devises. For example, as people's knowledge of the health consequences related to the exposure of workers chemicals have increased, improving ventilation system or wearing protective devices have enhanced the protection of the workers (Stellmen, 1998). However, with the growing concerns of the community on eliminating the emission or exposure of the toxic chemicals, the public became increasingly aware of and actively participated in environmental management. Hence, as the people became aware of that occupational health and safety issues and the working environment have become linked to environmental issues, EHS management in work environments was given a special attention (Stellmen, 1998).

Traditionally, EHS investments have been looked upon as being expensive. However, with present day's fast-paced and competitive environment, all components of business organizations are being asked to demonstrate their value to the organization and environment. Therefore, organisations try to invest in strong EHS management on behalf of the betterment of environment and keeping people healthy and safe. EMS involves creating a systematic approach to managing waste, complying with environmental regulations, or reducing the company's carbon footprint. Organisations have experienced many benefits of incorporating these environmental and health and safety measures into the workplace. When there is establish good waste management concept leads to reduce waste, utilization of fewer raw materials and costs. In addition, by managing environmental issues before a problem arises, companies benefit from reduced liability. Successful EHS programs also include measures to address ergonomics, air quality, and other aspects of workplace safety that could affect the health and well-being of employees (International Financial Corporation, 2007). Even though, a less attention has received to this subject, managing the EHS factors can also achieve the organizational financial goals and objectives.

3. ENVIRONMENTAL HEALTH AND SAFETY IN HEALTHCARE FACILITIES

Out of other business sectors, healthcare sector is specific from others. Customers and workers in healthcare facilities are exposed to various mixtures of chemicals in the working environment. Therefore, many EHS issues can be identified in health-care sector, and they end with serious damages to the lives of customers as well as the reputation damages to the hospital (Egbu and Liyanage, 2008). Therefore, inability of controlling such issues will lead to epidemic to the whole society (Egbu and Liyanage, 2008). According to the recent incidents, the reliability of healthcare sector has reduced (Sattler and Lipscomb, 2003). . The main reason is after admission, the infections has developed during the course of a stay in hospital. As Adams *et al.* (2008) mentioned, generally, 5% to 30% of patients develop one or more infections during a stay in hospital. Further, Legionellos is a well-established risk associated with health-care facilities, with an average proportion of health-care associated infections close to 10%. However, the development of infections during hospitalization can be minimised by managing better EHS practices in healthcare sector.

Most the healthcare workers including nurses and attendants are working in standing posture. However, sitting has certain advantages over standing (Grandjean, 1988). Therefore, work environment has to be designed according to the capabilities of the individual workers. Exposed high environmental heat load, the health impairment, and physiological damages occurred of the workers due to heat stress (Dinman, 1974). In addition, insufficient, too strong, or glaring illumination causes visual inefficiency, resulting in fatigue, headache, dizziness, and increased accident risk. Large amounts of time and money are lost due to visual inefficiency on jobs (Nakagawara, 1990). Further, workers are exposed to various kinds of noise in their working environment. Some kinds of noise not be harmful but are annoying. However, exposures to extremely loud noises (<20000Hz) caused temporary or permanent hearing losses. Noise in general, is annoying sound that can inversely affect safety and performance as well (Smith and Tayyari, 2003). As Chukwuma (1998) mentioned, chemists exposed to elevate levels of chemicals in the workplace experience various degrees of cancer of the pancreas, lymphatic and vascular systems, as well as spontaneous abortions, birth defects, low in addition, impaired sperm production. Further, a paternal exposure to various chemical has been associated with childhood defects or cancer. Therefore, EHS practices should be given a high attention in order to minimise the impact, which happens to performance of healthcare facilities due to above EHS issues.

4. FACTORS AFFECTING TO THE EHS IN HEALTHCARE ENVIRONMENT

In order to address the EHS issues in healthcare facilities and to address those issues, a better understanding on the factors affecting EHS in healthcare facilities is necessary. A comprehensive literature survey and desk study was carried out to identify the EHS factors related to healthcare facilities. The findings of the review are given in Table 1. The identified factors were categorized into two sections environmental and occupational health and safety related factors.

Table 1: EHS Factors Identified through Literature Review

EHS Factors	Literature Source									
	International Financial Corporation (2007)	Gershon et al. (2008)	Adams, et al. (2008)	Commission (2011)	WHO (2013)	Sadleir (2013)	Wangsaatmaja (1997)	Clever (1981)	Anon (2013)	Lundstrom et al. (2002)
Environmental Factors										
Air Emissions and Ambient Air Quality										
Water Conservation										
Waste Management										
Waste water and Ambient Water Quality										
Noise										
Occupational Safety and Health Related Factors										
Physical Hazards										

Chemical Hazards										
Biological Hazards										
Psychosocial Hazards										
Radiological Hazards										
Ergonomics										
Infection Safety										
Food Safety										

4.1. AIR EMISSIONS AND AMBIENT AIR QUALITY

Environment of a healthcare facility is generally contaminated with harmful substances. Where infected and susceptible people share the same air space and there is a risk of airborne transmission of infection (Jensen *et al*., 2005). Therefore, all occupied areas of the health-care facility should be adequately ventilated to meet comfort requirements. As Jensen *et al.* (2005) mentioned, ventilation rates should be maximized to dilute and remove any infectious particles.

4.2 WASTE MANAGEMENT

The public is increasingly concerned over the improper disposal of medical waste, particularly those contaminated with communicable disease agents. Medical wastes include all types of wastes generated by health care organisations such as hospitals, clinics, physicians' offices, dental offices, veterinary facilities, other medical laboratories and research facilities. The medical waste can be categorized into several types like sharps, bio-degradable, radioactive, hazardous and non-bio-degradable. When managing the waste, it has several ways like 3R concept (Reduce, Reuse and Recycle), combustion and composting (Wangsaatmaja, 1997). According to the Chukwuma (1998), lack of an adequate management system creates a large risk for the spread of infection, parasitic and epidemic diseases, through people involved in the collection or handling the waste.

4.3. WASTEWATER TREATMENT

Wastewater is produced from washbasins, showers, sinks, etc. (grey water) and from flushing toilets (black water) (WHO, 2002). It should be removed in standard waste drainage systems to off-site sewer or on-site disposal systems. All open wastewater drainage systems should be covered, to avoid the risks of disease vector breeding and contamination from direct exposure. The most appropriate wastewater disposal option is connecting the health-care setting to a properly built and functioning sewer system, which is, in turn, connected to an adequate treatment plant. If the sewer does not lead to a treatment facility, an on-site retention system with treatment will be necessary before wastewater is discharged (WHO, 2002). According to Cheremisinoff and Shah (1990), in developed countries, most hospitals are connected to relatively large community waste disposal systems and hospital wastes represent only a small fraction of the volume of sewage. A major concern in the disposal of hospital waste is that hospitals have their own sewage treatment facilities (usually found in developing countries). Smaller systems may be more hazardous owing to smaller volumes of wastewater and hence, less dilution of contaminants. Furthermore, smaller systems are less efficient and may permit the discharge of infectious agents into ground water or other media, which may, in turn permit these agents to survive, a hazard to both hospital personnel and the nearby community. The general wastewater treatment methods depend on biological processes, principally bacteria feeding on organic material in the wastewater. If the composition of the wastewater is significantly modified by the addition of chemical or toxic, solvents are allowed into sewer/drains, the operation of the treatment plants can be seriously affected, perhaps making them completely ineffective for some days.

Therefore, hospital wastewater deserves to be given more attention in terms of environmental problems (Wangsaatmaja, 1997).

4.4. *WATER CONSERVATION*

Healthcare facilities are generally operated 24 hours a day throughout the year and therefore they require a huge amount of for their operations. However, when dealing with increasing demand on water supply or water shortage problem and environmental awareness, water conservation is becoming a pressing issue (Wangsaatmaja, 1997). Further, water quality is also an important factor to be considered in healthcare EHS management. Water purification is an expensive and difficult undertaking, for a hospital and a clean water supply and delivery system should be guaranteed by the authorities. Water is often supplied by the municipal water authorities and is the stored before distribution through the hospital. Such stored water must be monitored for contamination at regular intervals (Mehtar, 1992).

4.5. *NOISE*

Healthcare workers are exposed to various kinds of noise in their working environment. Some kinds of noise not be harmful but are annoying. However, exposures to extremely loud noises (<20000Hz) caused temporary or permanent hearing losses. Noise in general, is annoying sound that can inversely affect safety and performance as well (Smith and Tayyari, 2003). No employee should be exposed to a noise level greater than 85 dB for a duration of more than 8 hours per day without hearing protection. In addition, no unprotected ear should be exposed to a peak sound pressure level (instantaneous) of more than 140 dB. The use of hearing protection should be enforced actively when the equivalent sound level over 8 hours reaches 85 dB, the peak sound levels reach 140 dB, or the average maximum sound level reaches 110dB(A). Hearing protective devices provided should be capable of reducing sound levels at the ear to at least 85 dB (International Financial Corporation, 2007).

4.6. *PHYSICAL HAZARDS*

The occupants of healthcare facilities can be subjected to various physical hazards as in other environments do. Physical hazards represent potential for accident or injury or illness due to repetitive exposure to mechanical action or work activity. Single exposure to physical hazards may result in a wide range of injuries, from minor and medical aid only, to disabling, catastrophic, and/or fatal. Multiple exposures over prolonged periods can result in disabling injuries of comparable significance and consequence (International Financial Corporation, 2007).

4.7. *CHEMICAL SAFETY*

Chemical hazards represent potential for illness or injury due to single acute exposure or chronic repetitive exposure to toxic, corrosive, sensitizing or oxidative substances. They also represent a risk of uncontrolled reaction, including the risk of fire and explosion, if incompatible chemicals are inadvertently mixed (International Financial Corporation, 2007). In addition, some chemical dusts can enter the organism and pass to the bloodstream, thus being carried through the organism and exerting toxic action on one or more organs or systems, e.g., kidneys, liver, blood. The healthcare industry is utilised high amount of various types of chemicals. Drugs, laboratory chemicals, cleaning chemicals, laundry chemicals are used frequently compared with other industries. However, proper chemical handling has to be applied to achieve a better performance.

4.8. *BIOLOGICAL HAZARDOUS*

Biological agents represent potential for illness or injury due to single acute exposure or chronic repetitive exposure. For employees' highest level of hygiene and personal protection, biological agents should be designed to enable their full segregation and isolation in emergency circumstances, include independent ventilation systems, and be subject to standard operating procedures requiring routine disinfection and sterilization of the work surfaces. HVAC systems should be equipped with High Efficiency Particulate Air (HEPA) filtration systems. Equipment should readily enable their disinfection and sterilization, and maintained and operated so as to prevent growth and spreading of disease agents (International Financial Corporation, 2007). There are three important modes of disease transmission from patients to staff. They are airborne and droplet aerosol exposure, skin contact exposure and exposure to infectious fluids via broken skin, eyes, mucous membranes, and parenteral exposure. If acute exposure to a biological hazard does occur, staff members need to be aware of relevant policies and procedures for appropriate management of the exposure. This will include appropriate washing for mouth, eyes or skin exposure, first aid for penetrating sharps injury, prophylaxis for high risk exposure, testing of the source if possible, testing and follow up of exposed staff and incident reporting (Sadleir, 2013).

4.9. RADIATION EXPOSURE

There is a wide range of radiation hazards related to medical imaging (X rays, nuclear scans utilizing radioactive isotopes, PET CT Scanner) and radiation oncology which utilizes ionizing radiation from a variety of sources to treat a range of malignant tumors. These sources include sealed sources containing radioactive material such as isotopes of radium, cobalt and strontium, and linear accelerators emitting short wave length gamma waves (Sadleir, 2013).

The use of radiation in medicine has led to major improvements in the diagnosis and treatment of human diseases. Annually, worldwide, more than 3,600 million X-ray examinations are performed, 37 million nuclear medicine procedures are carried out, and 7.5 million radiotherapy treatments are given. As the benefits for patients gain recognition, the use of radiation in medicine increases. While the development of modern health technology makes new applications safer, their inappropriate use can lead to unnecessary or unintended radiation doses, and can cause potential health hazards for patients and staff. Specially Children are vulnerable to environmental threats and have a longer life-span to develop long-term radiation-induced health effects like cancer (WHO, 2013).

4.10. ERGONOMICS

Disorders of the musculoskeletal system represent a main cause for absence from occupational work. The main work factors associated with these injuries are forceful exertions and awkward postures during patient- care tasks, especially while lifting and moving patients (Galinsky *et al.,* 2001). Musculoskeletal disorders lead to considerable costs for the public health system. Specific disorders of the musculoskeletal system may relate to different body regions and occupational work. For example, disorders in the lower back are often correlated to lifting and carrying of loads to the application of vibration. Upper-limb disorders may result from repetitive or long-lasting static force exertion or may be intensified by such activities. The severity of these disorders may vary between occasional aches or pain to exactly diagnosed specific diseases (WHO, 2013).

In addition, awkward postures or movements such as bending and/or twisting, raised arms, bent wrists, over reaching and over exertion; repetitive activities/handling, prolonged standing such as in the operating theatre at the operating table or in the kitchen, often combined with a bent over or awkward position; sitting while doing administrative work and documentation, often also combined with screen working. The stress engaged with the occupation is another factor that badly affected to the effective and efficient performance (Commission, 2011). Therefore, the design of work tasks or work station according to the capacity and performance of the worker is the most promising approach for preventing injuries, and for enhancing the comfort and safety of workers and patients (Galinsky *et al*., 2001).

4.11. PSYCHOLOGICAL HAZARDS

Psychosocial risk factors can arise among all occupational groups in the healthcare sector including nurses, doctors, cleaning staff and those in the medical-technical service. However, they can also be stressful for staff due to shift work or on call duty; high work load and demand; unrealistic patient expectation; verbal abuse or threat from disgruntled or intoxicated patients; high or unrealistic expectations from supervisors and management; frustration due to limited resources, especially staffing levels; time pressure; rigid hierarchical structures; lack of gratification and reward; inadequate personnel leadership; lack of relevant information; lack of support from management staff and social conflicts, harassment, bullying, violence and discrimination (Commission, 2011). Hospitals are part of a high demand, high expectation service industry and are heavily reliant on staff for the friendly, safe, effective and efficient delivery of services. To optimize productivity and attitude of staff, senior management must be committed to ensure a conducive organisational climate with high staff morale. Clear priorities and direction, realistic performance goals and workloads, commitment to continuing education and quality assurance, reception to staff feedback, and support with counseling services for stressed staff are all important components (Sadleir, 2013).

4.12. INFECTION SAFETY

Health care-associated infections lead to death, disability and excess medical costs. Infection control is an important matter for employees and patients. Hepatitis B (HBV) is the major hepatitis threat to hospital employees who come into contact with patient blood (the chief culprit) and secretions. The current consensus is that patients with HBV pose more of a danger to employees than vice versa, although scattered employee-to-patient reports have appeared.10 Hemodialysis, oncology, blood bank and venipuncture personnel are at highest risk (Clever, 1981). Unsafe health-care settings contribute to a significant proportion of some diseases. Sharps waste, although produced in small quantities, is highly infectious. Contaminated needles and syringes represent a particular threat because they are sometimes scavenged from waste areas and dump sites, and reused (Adams *et al*., 2008). HealthCare facilities must implement infection prevention and control policies like hand hygiene, personal protective equipment, isolation precautions, aseptic technique, cleaning and disinfection, sterilizations, waste management, immunizations and exposure management and antibiotics use protocol (WHO, 2013).

4.13. FOOD SAFETY

Foodborne diseases take a major toll on health. Millions of people fall ill and many die as a result of eating unsafe food. Food safety encompasses actions aimed at ensuring that all food is as safe as possible. Food safety policies and actions need to cover the entire food chain, from production to consumption (WHO, 2013). Food handlers should wash their hands after using the toilet and whenever they start work, change tasks, or return after an interruption. Soap and water should be available at all times during food preparation and handling, to ensure that hand washing can be done conveniently. Food handling and preparation is done with utmost cleanliness. Contact between raw food stuffs and cooked food is avoided. Food is cooked thoroughly. Food should be kept at safe temperatures and safe water and raw ingredients are used (Adams *et al*., 2008). The HACCP (Hazard Analysis Critical Control Point) is a well-established food safety system of hazard analysis which is derived from the NASA space programme, which would ensure food for astronauts would not lead to food poisoning. The system they developed was Hazard Analysis - Critical Control Point or HACCP (Lloyd, 2013). This system is frequently used by many organisations.

5. SUMMARY AND FUTURE RESEARCH AGENDA

According to Bohdanowicz *et al*. (2005), healthcare facilities have been found to have the highest negative impact on the environment of all commercial/ service buildings. And compared to other facilities, a large amount of health and safety hazards are also available in healthcare environment.

EHS factors negatively affect different levels healthcare organisations. Therefore, managing and implementing proper EHS strategies lead to improve the productivity and achieve the business objectives and of healthcare organisations.

Having a proper understanding on EHS factors is essential to take preventive measures to minimise the EHS issues of a healthcare facility. The study identified thirteen EHS affecting the EHS issues in healthcare facilities. The identified factors were classified into two groups namely environmental factors and occupational health and safety related factors. Among them ergonomics, physical, biological, chemical, radiation, psychological hazards, infection safety and food safety were identified as the health and safety factors. In addition, air emissions and ambient air quality, waste management, water conservation, noise, waste water and ambient water quality were identified as environmental factors. Both environmental and health and safety aspects act as a two sides of the same coin. Therefore, the objective of EHS management should be to find ways to protect both workers' health and safety and the broader environment (Stellmen, 1998).

Though occupational safety and health has popular among industry sector, managing impacts of the environment, safety and health of the customer as well as workers has to be considered. The research done by this subject is much less compared with other areas including occupational safety and health in hospital sector. The consideration of environmental factor of the healthcare sector is important and therefore the future research agenda would be to carry out an in-depth study to identify the most critical EHS factors affecting EHS of healthcare facilities.

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FREQUENTLY CHALLENGED DETERMINATIONS OF THE ENGINEER IN SRI LANKAN CONSTRUCTION CONTRACTS

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ABSTRACT

A sustainable procurement system should be capable of delivering a project free of disputes in its ideal perspective. However, disputes seem to be inevitable in construction projects resulting from its complex nature and involvement of different players in a temporary team setup which are conducive for conflicts. Thus, effective strategies to minimize disputes are the best potential contribution towards sustainability. In general, the Engineer is responsible to resolute the conflict since almost all the construction contracts empower the Engineer to give his fair determination in such situations. Better performance of Engineer's fair determination function would no doubt prevent the increase of project costs and time, by avoiding frequent dispute resolution referrals, and eventually minimize the resulting inefficiencies. In that scenario, the Engineer plays an extremely important role in a construction project. However, requirement of giving fair determination of the Engineer has been often debated in recent times. Engineer's determinations are often challenged devaluing the role of Engineer and putting the parties to lose their money on expensive dispute resolution procedures. This research was focused on identifying the situations where Engineer's determination is challenged in Sri Lankan context. The study was based on a documentary survey and finds that most frequently challenged decisions are related to adjustment for cost escalation, delayed instructions and fixing rates for variations. The findings are useful in formulating strategies to minimize such instances.

***Keywords:** Construction; Disputes; Engineer's Determination, Sri Lanka.*

1. INTRODUCTION

Most construction contracts require fair determination by the Engineer for conflicts arising between the employer and the contractor. However, there has been many instances that this determination is challenged causing the parties sorting resolution through Alternative Dispute Resolution (ADR) or litigation incurring additional cost not only in terms of finance but also in terms of time, business relationships, and reputation. These costs do not add any value to the building project and therefore negatively affect the sustainable project delivery. It is imperative to develop solutions to minimize such challenges. As an initiative, a study was conducted to identify the most frequently challenged Engineer's determinations to help prioritizing solution development endeavours.

2. BACKGROUND

Success of a construction project relies on the three most important stakeholders of the project viz. Employer, Engineer (Consultant) and Contractor. Among them, the Engineer plays a vital role to ensure the time, cost and quality targets are met (Potts, 2008; Wang & Huang, 2005). The

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International Federation of Consulting Engineers' (FIDIC) Conditions of Contract for Construction - Red Book defines: "Engineer means the person appointed by the Employer, to act as Engineer for the purposes of the Contract and named in the Appendix to tender, or other person appointed from time to time by the Employer and notified to the Contractor". It further states that, if any conflict arises between Employer and Contractor, Engineer should consult both parties to reach an agreement. If the parties could not reach an agreement, Engineer should make a fair determination in accordance with the contract, taking due regard of all relevant circumstances (FIDIC, 1999).

The importance of guaranteeing that the Engineer acts fairly, where he is appointed with the duty of administrating a contract, and where such Engineer is paid for his services by the Employer, is often highlighted in practice (Samaratunga, 2009). Further, the Engineer is sometimes accused by the Employer for being biased towards the Contractor during the administration of the contract such as awarding extensions of time, in determining amounts of claims, and giving instructions in favour of the Contractor (Bunni, 1997). Even though the Engineer's fair determination is required by most standard Conditions of Contract (COC); there has been enough evidence that his impartiality is at times challenged (El-Adaway & Ezeldin, 2007).

Theoretically, in a perfect condition, a determination by the Engineer is not expected to be challenged by the parties, since dispute resolution process would not deliver an alternative result. However, in imperfect conditions, Engineer's decision may be challenged, expecting a different outcome through the dispute resolution process. However, in practice, the challenge to the Engineer's impartiality or fairness should not necessarily arise from him being partial or unfair. It may arise from the fact that his act does not provide evidence to show his impartiality while he is in fact impartial. Whatever the cause might be, if the Engineers determination is not accepted, it is likely to cause disputes adversely affecting the project success. Understanding about what determinations are usually challenged will help to develop strategies to minimize such challenges. Therefore, this research was focused on identifying frequently challenged determinations of the Engineers in Sri Lankan construction contracts with the purpose of presenting a knowledge base to develop strategies to minimize such challenges in future.

3. ENGINEER'S DETERMINATIONS

The primary focus of the literature review conducted was to identify the Engineer's determinations potentially be challenged by main contracting parties. The study began by identifying the Engineer's role. Bunni (1997) identifies the Engineer as a designer, as a supervisor, as a certifier and as an adjudicator or quasi arbitrator. Though this scope is beyond the FIDIC (1999) definition herein above mentioned, how Bunni identifies the role is from the perception of the stakeholders in the construction industry. The identification of Engineer's role as adjudicator and quasi arbitrator highlights the requirement of fairness and impartiality.

In absence of suitable list of Engineer's determinations required to develop the research hypotheses, a number of previous research work on sources of disputes were reviewed to identify the challenged determinations found in them. The works reviewed are listed along with a brief description about the nature of their study in Table 1.

Table 1: Literature Summary on Types/Sources of Disputes

Reference	Types/Sources of disputes analysed
Bekele (2005)	Disputes between Client and Engineer, disputes between Client and Contractor, disputes between Engineer and Contractor
Chan and Suen (2005)	Contractual matters, cultural matters and legal matters
Cheung and Yiu (2005)	Construction related and human behaviour related
Genton and Schwab (2000)	Delays/ accelerations, quality and performance, operation/guarantee period, financial issues

Reference	Types/Sources of disputes analysed
Jahren and Dammeier (1990)	Changed conditions, Payment issues, Time and delays, Errors in bids, Lack of communication
Kumaraswamy (1998)	Time claims, cost claims, construction claims
Knowles (2005)	Design, tenders, extensions of time, global claims, liquidated & ascertained damages, program, payment, variations, loss and expense, practical completion & defects, right & remedies and adjudication
Zaneldin (2006)	Changes claims, extra-work claims, delay claims, different site conditions claims, acceleration claims and contract ambiguity claims

The identified determinations were grouped in a suitable manner for the field study and analysis. FIDIC (1999) COC was used as the basis for identifying and defining the determinations. Selection of the FIDIC document for this was primarily due to researches' familiarity and its international acceptance; while one of other common standard COC would have served the purpose, researchers found this document would help consistent categorization with ease. The findings were logically tabulated with 12 categories and 49 subcategories as shown in Table 2. A group of categories with remote occurrence of challenge were combined to create a combined category "Miscellaneous" to make a more populated category and ease the analysis.

Table 2: Engineer's Determinations

Category of challenges	Subcategories (Type of Disputes)
Variations and Adjustments	Engineer's instruction on variation
	Fixing of rates in variation
	Value engineering
	Adjustment for changes in Legislation
	Adjustment for the cost of labour, Goods and other inputs to the Works (Escalation)
Commencement and Delays	Delay works due to Authorities
	Delay caused by Employer, Employer's personnel or Employer's other Contractors
	Delay due to exceptionally adverse climatic conditions
	Delay caused by variations
	Delay due to unforeseeable shortages in the availability of personnel or Goods
	Prolongations costs
	Delay due to third party actions
	Delay damages
Incompetence of work	Delayed drawings or instructions from Engineer
	Delayed instructions from Engineer on Fossils
	Changes in scope of work
	Inadequate soil investigation report
Defects in contract document	Misinterpretations of contract documents
	Errors in contract document
	Omissions in contract document
Quality and performance	Contractor fails to maintain rate of progress
	Rejection of Plant, Material or workmanship
	Remedial Work
	Testing (If Contractor suffers delay and/or incurs cost from additional testing)
	Testing (If failure in the test, Employer issue Taking over Certificate and cover cost for recovery)
	Interference with Test on Completion
	Failure to serve notices

Category of challenges	Subcategories (Type of Disputes)
	Failure to adhere to the design
Site availability	Delay in giving of possession of Siteby the Employer
	Lack of assistance to obtain work permits, licenses or approvals by the Employer
Measurement and Evaluation	Evaluating each item of work to agree or determine the Contract Price
	Omissions of any works forms part of the variation
Cease of work	Suspension of Works by the Contractor
	Termination of Work by the Contractor
	Termination of Works by the Employer
	Suspension of Works by the Engineer
Payment	Valuation of works in Interim Payment Certificate
	Schedule of payments
Employer's Taking Over	Additional cost/time for Taking Over and/or using a Parts of the Work
	Acceleration cost
Defects liability	Extension of Defect notification period
	Failure to Remedy Defects
	Contractor to search for the cause of any defect
Miscellaneous	
Employer’s Risks	Consequences of Employer's Risks; war, terrorism etc.
Insurance	Insurance
Force Majeure	Consequences of Force Majeure
Unforeseeable physical conditions	Due to unforeseeable physical conditions on site
Setting Out	Due to errors in reference points and levels for setting out
Use of Employer's properties	Use of Employer's Electricity, Water and Gas
	Use of Employer's Equipment and Free-Issue Material
Corruptions	Corruptions
Nominated sub contractor	Nominated sub contractor related

4. RESEARCH METHODOLOGY

Once a determination of the Engineer is challenged, it is taken to next stage of conflict management procedure in a contract. This is often adjudication or arbitration. Thus, adjudication and arbitration cases were identified as the unit of analysis. Data was collected from reviewing adjudication and arbitration submissions. Since these submissions are confidential documents, data collection became a challenge. A data collection sheet which recorded only the number of occurrences of each determination challenged helped convincing the participants to allow access to documents. Still, the data collection was a challenge as the researchers had to review the document searching for data. At times, when the researches were confused or the documents did not clearly point the facts, assistance from the participant (i.e. the adjudicator or arbitrator as the case may be) was sought. Using this approach, 110 Engineer’s determinations challenged were counted. Frequency distribution was used as the primary method of data analysis.

Selection of participants was by convenience that they would be willing to support the study. However, this should not have affected the representativeness of the sample because the identity of the dispute resolver would not affect the types of disputes occur. It should also be noted that, not all the documents related to disputes were given access to; but a limited set of documents, and sometimes limited pages from documents, appropriate enough to collect required data as determined by the participants were provided for review. Researchers found that it was difficult to distinguish if a dispute over delayed payment or a non-payment was a challenge to the Engineers determination or was an Employer’s default, from the provided level of access. As a result, data collected excludes occurrence of challenges to Engineers determination resulting in delayed or withheld payments. This was a limitation of this study. However, other types of determinations related to payments were counted.

5. RESEARCH FINDINGS AND DISCUSSION

The relative frequencies challenged determinations in each of the 12 categories identified in Table 2 are shown in Figure 1. It was evident that the most challenged determinations were related to Variations, Delays, own performances and defects in contract documents. Table 3 presents determination which had been challenged more than five times (i.e. > 5%). A discussion on top listed categories and challenged determinations follows.

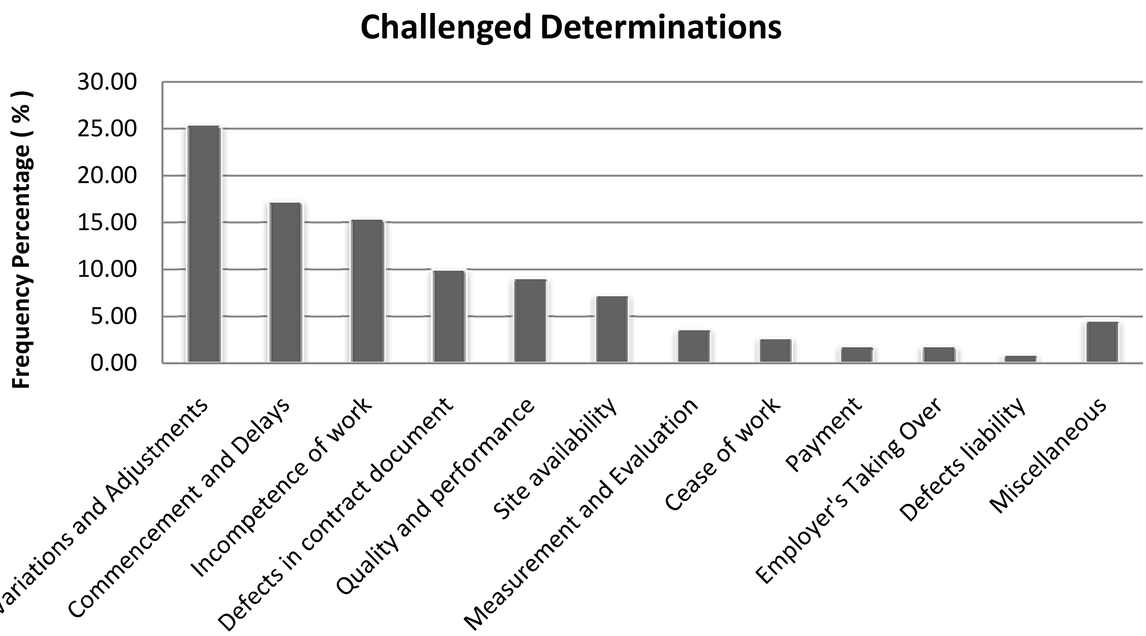

Figure 1: Distribution of Frequencies within Categories of Events

Table 3: Frequency of Challenged Determinations

Type of Determination	Category	Freq.
Adjustment for the cost of labour, Goods and other inputs to the Works	Variations and Adjustments	12
Delayed drawings or instructions from Engineer	Incompetence of work	8
Fixing of rates in variation	Variations and Adjustments	8
Engineer's instruction on variation	Variations and Adjustments	6
Changes in scope of work	Incompetence of work	5
Delay caused by variations	Commencement and Delays	5
Delay in giving of possession of Site by the Employer	Site availability	5
Misinterpretations of contract documents	Defects in contract document	5
Prolongations costs	Commencement and Delays	5

5.1. VARIATIONS AND ADJUSTMENTS

'Variations and Adjustments' category is the most frequently challenged determination category of the Engineer representing 25.45% from total number of challenged disputes in the sample. It consists of three significant subcategories (i.e. types of determinations).

Adjustments for the cost of labour, goods and other inputs to the works (Escalation)

Adjustments for the cost of labour, Goods and other inputs to the Works (Escalation)' has acquired a 42.86% within the category and 10.91% from the total determinations that were challenged. In Sri Lanka, most contracts use ICTAD formula method (see ICTAD, 2008) for adjustments for fluctuations in prices. It was found that some determinations on adjustment for cost using ICTAD method and/or indices has been challenged by the Contractors. However, they were not in fact challenging the ICTAD method; instead the disagreements were about the selection of price indices which they argued not sufficiently compensating their losses from price escalations. The challenges had arisen when applying resource input percentages and deciding on relevant price adjustment category for inputs.

Increase in fuel prices was another major reason that has caused some of the disputes. The unexpected increase of fuel price has affected directly or indirectly to the price of every construction material, labour, plant and machinery rates. Some contracts do not allow adjustment for price escalations; contractors' claims for these losses presented relying on 'force majeure' clause had been rejected by the Engineers and this had often been challenged.

Fixing of rates in variation

Most COC provides for the Engineer to fix rates for varied work on his own estimate if he considers the quoted rate is inappropriate. This authority is often used by the Engineer. The research revealed that fixing the rates for varied works to be another key determination which was frequently challenged. The primary reason observed was the lack of agreement of markup (profits plus overhead cost) rate at the time of contract agreement. Employer was quite obscured in this context and it was usually seen as a dispute between the Engineer and the Contractor.

Engineer's instruction on variation

In some cases, Engineer's determination had been challenged when variation orders are issued. Contractors assert that some of the changes result in change of the contracted scope and thus oppose the issue of the change as a variation in accordance with the COC. The primary reason seems to be the Contractors' resentment for executing changed work items at the contracted rates (prices). This situation often occurs under fixed rates contracts when price adjustment for escalation is not provided. However, this would still occur even if the price adjustment was provided, especially when the change involves underpriced work items in the contract.

5.2. COMMENCEMENT AND DELAYS

Majority of this category of challenge relates to the extension of time. 'Prolongations costs' and 'Delay damages' have also considerably contributed to the challenges under this category. Most challenges were for the determinations on extension of time (EOT) for 'Delay caused by variations'. In general, EOT has to be substantiated by showing that the variation affects the critical path of the project programme. In some cases, the determination of the Engineer regarding the effect of the variation had been challenged. This category also counts in some determinations of the Engineer on global claims. While technically the determination ('rejection' in most cases) may be seen as result of poorly articulated claim, Contractors insist on their entitlement to EOT and associated cost notwithstanding the quality of the claims submitted. There were also situations where determinations of prolongations cost claims arising from restrictions imposed by Authorities being challenged by the Contractors.

5.3. INCOMPETENCE OF WORK

The COC assigns the Engineer to make determinations on losses and disruptions from 'delayed drawings or delayed instructions from Engineer'. Given the fact that some delays in giving instructions are unavoidable, this condition allows compensating any loss to the Contractor arising from them. However, the condition also sometimes perceived as biased (thus unfair) that the Engineer is given the authority to determine upon the effects of his own conduct. The Contractor's perception could be that the Engineer might not give a fair determination under this scenario because he would be troubled of reprisal from the Client. Thus, such determination would often receive suspicions resulting in being challenged. This situation is likely to occur due to delays occurring from incompetent work rather than unavoidable delays.

5.4. *DEFECTS IN CONTRACT DOCUMENTS*

Standard COCs are often amended by the Engineer when used in contracts. It was found that there were number of challenges to the Engineers determinations which involved interpretation of contract conditions. A larger majority of the disputed determinations were related to amendments made to standard COC. Unlike standard or common COCs, external interpretations (such as text books) for amended conditions are difficult to find. As a result, Contractor clings on to his own interpretations while the Engineer upholds his own.

5.5. *QUALITY AND PERFORMANCE*

Quality is very much linked to the cost. Bidders usually price the tenders for the minimum expected quality of work as detailed in tender documents to offer a competitive price. Therefore, the winner, who is usually the one comes with lowest bid, is likely to be the one with lowest expected quality in mind (Tan & Suranga, 2008). This may be one of the reasons for the increased number of challenges under the 'Quality and performance' category. 'Rejection of Plant, Material or Workmanship' has been identified as the most frequently occurred dispute event in this category. Engineer as a supervisor, certifier or as an agent of Employer, has a right to reject the Plant, Material or workmanship of the Contractor. Consequently, there were disputes incurred challenging such determinations by the Engineer.

5.6. *SITE AVAILABILITY*

Making the site available for the Contractor is one of the major obligations of the Client (the Employer) under the contact and its delay would result in a global claim situation giving entitlement to EOT. It was found that EOT and related cost entitlements from 'Delay in giving possession of Site from Employer' are amongst the ten most frequently challenged determinations of the Engineer. While this is thought to be comparatively an obvious context, there have been instances the Engineer failed to grant extension of time and related cost, which were challenged by the Contractor.

5.7. *MISCELLANEOUS*

The other determinations related to events such as Measurement and Evaluation, Cease of work, Payment, Employer's Taking Over, Defects liability and miscellaneous categories were not found to be challenged in the sample. From the miscellaneous category, 'unforeseeable physical conditions' related determinations were found to be amongst the top ten determination challenges. Within this context, there were several disputes over the question of defining what could be and what could not be foreseeable.

5.8. *FREQUENCY OF THE DETERMINATIONS CHALLENGED BY A PARTY*

Figure 2 shows number of projects which had certain frequency of disputes challenging the Engineer's determination. Compiling of this information was possible since participants had kept documents related each project separate. Even though the researchers did not record the project identification data, they recorded data for each project separately with a codename (P01, P02, etc.). While the information does not directly address the aim of this study, it helps to understand the nature of the industry in terms of the spatial issues. It can be observed that the number of determinations challenged in a project usually varies between 1 to 5. This indicates that Engineers' determinations are not usually aggressively challenged.

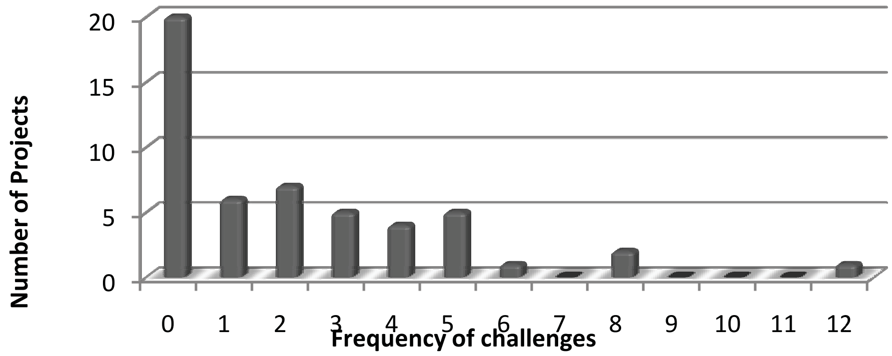

Figure 2: Distribution of challenging determinations of the Engineer

6. CONCLUSIONS AND RECOMMENDATIONS

The study finds most frequently challenged determination by the Engineer. The need was to provide the knowledge base to develop strategies to minimize the probability of such challenges. Engineer's adjustment for the cost of labour, goods and other inputs to the Works (Escalation) is the mostly challenged determination in the Sri Lankan construction industry. Most other instances of challenges are related to the skills and knowledge of the part of contractor and the Engineer. Therefore, it is recommended to find mechanisms to develop knowledge and skills in these fields. Standardize the practices among both Engineers and Contractors would help.

It should be noted that a challenge to a determination does not endorse that the determination had been wrong. A correct determination may be challenged if its presentation is not strong enough to convince the parties. Standardization would contribute solve this. Engineers' skills and attitudes shall be improved to present the determinations skilfully, and communication among parties shall be improved to minimize suspicions. Including the fundamentals of claims management into the academic curriculum of future Engineers (Consultants) would also be another strategy.

It was evident that Engineer's determinations were not aggressively challenged. Therefore it can be expected that a genuine attempt to minimize the instances of the determinations being challenged would give favourable results. Now that the critical areas are known, it shall be recommended to study further to find out ideal strategies to minimize the occurrence of challenges to Engineer's determinations.

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IDENTIFICATION OF A TECHNOLOGICAL FRAMEWORK FOR IMPLEMENTING BUILDING INFORMATION MODELLING IN SRI LANKA

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ABSTRACT

Building Information Modelling (BIM) is an important component in sustainable procurement strategies. With the rise in popularity, it is gaining the potential to be industry standard for building projects. By taking the digital design data to a new level, BIM promotes better integration and optimum use of resources for the sustainability in all aspects of construction. This is being experienced by more developed countries, which have gained benefits after successfully implementing BIM. Although BIM has not yet been implemented in Sri Lankan building industry, it is likely to be an option for consideration in the near future. As BIM is fully dependant on technology, determining a proper framework is an essential prerequisite. Considering the differences in the building industry among Sri Lanka and other countries, a generic framework will not be practically capable in facilitating such implementation successfully. Under this context, a research is conducted with the broader aim of determining a BIM technological framework for Sri Lanka, a special case where the current technology is minimal and funding ability is low. With preliminary findings from a literature review on the technological prerequisites of adopting BIM, this paper presents logical conclusions developed for technological aspects of implementing BIM for Sri Lankan building industry. The findings shall be a valuable source for all parties who are interested in utilizing BIM technology in the future for the sustainability in building industry of Sri Lanka.

Keywords: *Building Information Modelling; BIM; Construction; Sri Lanka; Sustainability.*

1. INTRODUCTION

The problems associated with the traditional design-bid-build procurement method are often conducive to Building Information Modelling (BIM) is a technology that is gaining worldwide attention which indicates the possibility of a paradigm shift in the building industry. Implementation of BIM is filled with challenges, adoption of technology being one. As Sri Lanka is yet to initiate BIM, developing a technological framework can be helpful in such implementation. This paper is a review of the current status of BIM in practice and technological prerequisites for it, which aims to build logical conclusions from the available knowledge. The work is a part of an ongoing research with the broader aim of developing a technological framework to facilitate implementation of BIM in Sri Lankan building industry.

2. BACKGROUND

The building industry is a well known latecomer to the productivity advantages offered by technology and its fragmented nature precludes widespread change of any kind, particularly to design tools that are based on the traditions of paper (Bernstein and Pittman, 2004). BIM is one such outcome of technology where a digital representation of physical and functional characteristics of a building is created with a shared knowledge resource for information about it that forms a reliable basis for decisions during its life cycle, from earliest conception to demolition (Construction Project Information Committee, 2011). Similarly Penttila (2006) stated that BIM is a methodology to manage

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the essential building design and project data in digital format throughout the building's life-cycle. BIM activity results in a 'Building Information Model', which is a three-dimensional parametric virtual model that enables a wide range of applications. BIM is not a software application. Instead it is an IT solution for integration of software applications and IT tools to design a building in a common platform, a platform which is independent of the software we use (Jayasena and Weddikkara, 2012). Therefore BIM can be clearly differentiated from traditional Computer Aided Design (CAD).

3. CAD VS BIM

BIM has to be differentiated from CAD. According to Royal Institution of Chartered Surveyors (2012), BIM changes the emphasis on a typical CAD model by making it the primary tool for documentation. It has enhanced information contained in virtual models (Grilo *et al.*, 2013) that are data-rich, object-oriented, intelligent and parametric in nature (Associated General Contractors of America, 2005). In contrast, Bernstein and Pittman (2004) explained the non-computable nature of CAD by comparing an output for a financial model created with a word processor and a spread-sheet. Although the output maybe visibly similar, the amount of work done may differ as a spread sheet has 'computable' data. Furthermore they stated, "The building industry, for the most part, has adopted the word processor approach to documenting building designs over the past 20 years" (Bernstein and Pittman, 2004). Luthra (2010) suggested that, the computable data of BIM puts it a step ahead of CAD files which constitute of raw data. Hence BIM can be considered as the better choice for the progression for the building industry.

4. SUSTAINABLE PROCUREMENT AND BIM ADOPTION

United Nations Global Marketplace (2010) defined 'Sustainable Procurement' as procurement which integrates requirements, specifications and criteria that are compatible and in favour of the protection of the environment, of social progress and in support of economic development, namely by seeking resource efficiency, improving the quality of products and services and ultimately optimizing costs. Building procurement deals with design, construction and operation, in which the sustainability is a major requirement in all these stages. Wong and Fan (2013) stated that BIM is a critical element in reducing industry waste, adding value to industry products and decreasing environmental damage.

The importance of BIM adoption is becoming increasingly recognised and BIM implementations and discussions continue to increase in intensity (Succar, 2009) due to its value adding potential to the building industry that has been facing barriers and challenges to improve productivity, efficiency, quality and sustainable development (Khosrowshahi and Aryici, 2012). Therefore BIM is now being increasingly used as an emerging technology in many countries, where they are currently in the process of or have released BIM guidelines (Wong *et al.*, 2009). The UK Cabinet Report published on May 2011 has announced the Government's intention to require collaborative 3D BIM (with all project and asset information, documentation and data being electronic) on its projects by 2016 (Poletayeva, 2011). BIM's use is promoted collaboratively by public and private sectors in the USA (Underwood and Isikdag, 2011) where it has gained a quick momentum with a 75% increase in usage between 2007 and 2009 with 93% of users believing it having the potential to gain more value in the future (Smart Market Report, 2009). Therefore it is evident that, BIM is getting wider attention and acceptance throughout the world.

5. BIM IMPLEMENTATION

Implementing BIM is a challenging task. Bernstein and Pittman (2004) had the view that, the transition to BIM based paradigms will be a greater shift than that of paper to CAD, as it entails a change in both tools and process. Smart Market Report (2009) highlighted the non-user perspective for BIM, in which lack of time to evaluate BIM, high costs for software/hardware upgrades, non identification of sufficient BIM compatible content for the relevant field are listed as some of the key setbacks. Eastman *et al.* (2008) recognized the most significant change that companies face when implementing BIM technology is intensively using a shared building model during design phases and a coordinated set of building models during construction and fabrication, as the basis of all work processes and for collaboration. To overcome most of these challenges, Arayici *et al.* (2011a) suggested a bottom-up approach for BIM implementation. However, such approach should be backed by a suitable basis for implementation.

As BIM is fully dependant on technology, utilizing a proper technological framework is an essential prerequisite. According to AEC (UK) BIM Protocol Project BIM Execution Plan (2012), the exchange of information between all stakeholders is a key factor in execution of a successful BIM project. To support this, even though a multitude of guidelines and reports are available, they do not provide sufficient foundational framework suitable for the systematic investigation of the BIM domain (Succar, 2009).

5.1. BIM SPECIFIC SOFTWARE

BIM software tools are characterised by the ability to compile virtual models of buildings using machine-readable parametric objects that exhibit behaviour commensurate with the need to design, analyse, and test a building design (Sacks *et al*., 2004). Over the years, many software vendors have developed off-the-shelf software focusing on BIM, such as Autodesk Revit, Autodesk Navisworks, Bentley Architecture, Graphisoft ArchiCAD, Innovaya Visual BIM, Vico Estimator, Exactal CostX, Solibri IFC Optimizer to name a few. When considering implementation of BIM in any level or scale, selection of software can be a key aspect. Table 1 summarizes the findings of three separate researches regarding requirements and aspects to consider when selecting software to implement BIM.

Table 1: Prerequisites of Selecting BIM Specific Software

Criteria	**(Khemlani, 2007)**	**(Won and Lee, 2010)**	**(Arayici *et al.*, 2011b)**
Ability to input data to dimensional accuracy			√
Ability to issue BIM information to other Consultants			√
Ease of export to other formats and re-import accuracy			√
Compatibility with various formats (ifc, gdn, skp, dwg, dxf, pdf etc)	√	√	√
Ease of creating fixed export (eg: PDF) and 3D PDF capability			√
Ease of multiple team members working on the same model	√		√
Ease of setting up drawing sets, schedules, standards, templates			√
Ease of creating the model and adding new libraries	√	√	√
Ease of navigating around the BIM model			√
Scalability (ability to work on large scale projects)	√	√	
Full support for producing construction documents	√		
Market share position of the BIM software vendor	√		√
The use of the same software by other major competitors		√	
Built-in ability to generate photo realistic renderings and animations	√		√
Smart objects connecting with other objects/ parametric features	√		√
Object types and libraries available	√	√	√
File sizes of the models created			√
Multidisciplinary capability	√		
Initial investment cost including training and license costs		√	√
User support, tutorials, manuals and learning curve	√	√	√
Contractual requirement of use of BIM software		√	

Apart from the prerequisites mentioned in Table 1, Luthra (2010) identified some of the common problems associated with technological aspects of BIM implementation and areas that need better attention, as listed below.

- Incompatibility problems (file formats/standards/ versions) and application programming interface (API) customization problems need to be addressed at the initiation.
- BIM technology should be exploited to improve present workflows rather than adapting organization work flows to match BIM software's workflows, emphasizing the value of information exchange to support design processes.
- Database normalization should be given a high priority, while all input data should be collected in detail at the first time.
- An integration plan amalgamating software acquisition plan, training schedule, hardware update schedule, explanation of technological shift, and strategy roll-out plan needs to be developed to determine efficiency of new systems as a yardstick.
- The existing information storage, retrieval and exchange capabilities of the firm will need to be critically assessed, especially for Industry Foundation Class (IFC) compliance. IFC is an open, neutral data format developed by buildingSMART. Furthermore, data creation needs to be maintained, filed, indexed and documented.

5.2. HARDWARE AND OTHER REQUIREMENTS

In order to set up a functional BIM platform, essential hardware and network requirements need to be fulfilled.

- Computers (Personal computers or servers) – These requirements are specified according to the software vendor depending on the scale of usage and functions (such as rendering capability and details)
- Connectivity – Data transfer mechanisms need to be set up. Basically a Local Area Network (LAN) within the central design office/ site office is required to connect all the relevant computers to facilitate data exchange among them. Wired or wireless connection facilities need to be associated for this purpose. Furthermore, when files need to be transferred to different locations via internet, a broadband or higher category connection has to be used as the files become larger in size with added information and complexity.
- Servers and Databases – These can be within a design or site office, enabling a central data repository for BIM usage.
- OpenBIM - This is a free, open-source, software development toolkit that allows developers to create bespoke BIM middleware for IFC-based applications (OpenBIM, 2012). It is a good alternative to the high cost off-the-shelf BIM applications and provides the basis to write software that focuses on the actual requirement. The free and open-source application development is highly beneficial to especially the developing countries which cannot afford the application packages for BIM.
- Mobile Applications – BIM enabling software such as BIMX which is developed for Android based devices (Smart phones, tablets etc) allow the users to extend the BIM capabilities by providing the much needed mobility. With sufficient processing power of the device, it allows to regenerate BIM models with walkthrough capabilities, allowing a better platform for BIM usage.
- Cloud computing – According to Varkonyi (2011), the most basic approach to cloud computing is when the cloud is considered as a giant server that anyone can access for a fee

(via internet), where users can store their files in the cloud with virtually unlimited storage space that dynamically scales; data can be remotely accessed from any computer in the network; files can easily be shared with others; and the data itself is stored in a much higher security environment. This concept is used for BIM via 'Cloud-BIM' approaches. It is a method to share resources (both software and hardware that are highly expensive) and improve information sharing for BIM purposes. Chuang *et al.* (2011) stated that the Cloud-BIM system is able to present significant information in multiple modes such as text and graphical formats, by accessing the database of the Cloud-BIM system. Figure 1 is an extraction from the same work which illustrates the arrangement of Cloud-BIM.

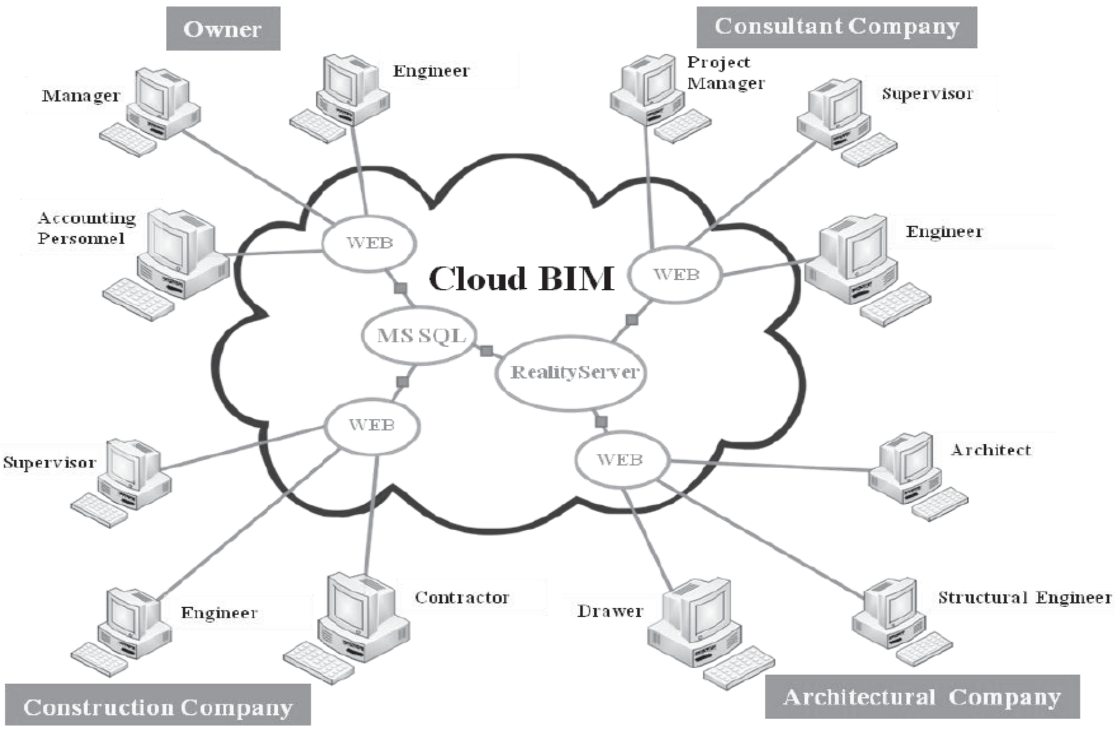

Figure 1: The Concept of Cloud-BIM (Chuang *et al.,* 2011)

5.3. BIM PLATFORMS

There are different approaches for BIM platforms when considering the data sharing methodology adopted. Basically two significant platforms can be identified.

There is, on the one hand, a group that strongly believes in working with a central data repository based on a single homogeneous software environment. On the other hand there are the believers of freedom for a project partner to choose its own software tools. This group also tends to believe in a shared data repository, but finds this has to be based on an open data model like IFC. We call these groups 'homogeneous software environment' and 'plural data environment'. Both propagate arguments on different levels of technology, usability and efficiency (Van Berlo *et al.,* 2012).

Based on the findings and conclusions of Van Berlo *et al.* (2012), Table 2 summarizes a comparison between Homogeneous software environment and Plural data environment.

Table 2: Comparison between Homogeneous and Plural Data Environments for BIM Platforms

Criterion	Homogeneous Software Environment	Plural Data Environment
Data sharing platform	Uses central data repository	Can use shared or central data repository
BIM Software	Proprietary applications/suites – Forced to select the same software for 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 engineering tasks
Data exchange	Mostly based on file formats that depend on the selected software	Mostly based on IFC data model
Data amalgamation/ Data fusion	Performed via live synchronization 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.

6. TECHNOLOGICAL ASPECT OF BIM ADOPTION IN ASIA

In comparison to most Western countries that have already implemented BIM in major scale, Asian countries still have not initiated it in a similar extent yet. But a notable exception is Singapore where there is direct government involvement in implementing BIM. Even though there is no separate technological framework for BIM introduced, Building and Construction Authority (2012) mentioned some guidelines, for instance; collaboration parties should agree upon the BIM exchange protocol and submittal format (proprietary or open standard) in the BIM execution plan. Khemlani (2012) stated that China is indirectly advocating the use of BIM although it is not mandating BIM outright. Considering the construction sector of Hong Kong, Wong *et al,* (2009) suggested that a possible BIM policy should encourage open standard software development in relation to BIM. Meanwhile Luthra (2010) suggested that software licensing and training should be looked at as components of a strategic investment, while it is required to develop an integration plan amalgamating software acquisition plan, training schedule, hardware update schedule and explanation of technological shift for the Indian construction industry. Therefore it is clear that the technological aspect of BIM adoption in Asia is in different levels of maturity at present.

7. TECHNOLOGICAL ASPECT FOR FACILITATING BIM ADOPTION IN SRI LANKA

Sri Lankan building industry lags behind in any sort of BIM implementation compared to more developed countries that have successfully adopted and gained benefits of it. The following are some findings that provide insight to this situation.

- According to Reginold (2009), it was identified that the low level of usage of Information and Communication Technology (ICT) can badly affect to the construction productivity in Sri Lanka, hindering the ability to reach sustainable construction practices.

- Navaratna (2006) emphasized that Sri Lankan authorities have not given sufficient attention to improve construction productivity with use of ICT. This affects the ability to adopt BIM in the country.
- The general observations, especially in the public sector of construction which holds 74% construction value (Department of Census and Statistics Sri Lanka, 2011), suggested that, there is a high reluctance to invest in Architecture, Engineering and Construction (AEC) related software. As a result, there will be a significant impact when shifting to BIM specific software and hardware, which will require a high initial investment.
- The expenditure of only 0.11% of Gross Domestic Product in 2008 for research and development (The World Bank – Research and development expenditure, 2013) is significantly less than that of most other BIM implemented countries.

However, Jayasena and Weddikkara (2012) predicted that, once available, adoption of technology would not be a challenge in a nation with comparatively high ICT literacy and AEC professionals with fair computer knowhow.

8. CONCLUSIONS

BIM is a technology that provides the long awaited edge to the building industry over other manufacturing industries that benefit from automation. In comparison to traditional CAD which has its own uses, BIM enables totally machine readable building data with the use of strong information schema. It is gaining popularity and the countries that have implemented BIM have reaped its benefits already. The adoption of BIM has many aspects to consider, technological aspect being one. A systematic approach is required to identify the key components that require for implementing BIM. Sri Lankan building industry lags behind most of the Information Technology based advances. Therefore there is an essential need to overcome the technological barrier of BIM that hinders any progress in Sri Lanka. Hence a proper technological framework for BIM adoption will be a key requirement. Deciding on this framework, the first decision to make would be the choice between homogeneous software environment and plural data environment. The lack of technological advancement in the industry may further become a blessing in disguise in this context since it offers high flexibility to choose the right technology for strategic investors in BIM for their projects.

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IMPACT OF GOVERNMENT POLICIES AND REGULATIONS WHEN ADOPTING ALTERNATIVE PROCUREMENT METHODS

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ABSTRACT

The freedom to choose a procurement method will significantly affect the sustainability of the project delivery process and the operation of the building as well. Even though there are number of different procurement methods subsist in the industry, traditional procurement methods and design and build procurement methods are dominate the Sri Lankan construction industry where some conventional procurement methods have numerous inefficiencies inherently or arising from specific contexts of application. With the development in the construction industry number of projects will towards to achieve the sustainability where difficult to adopt traditional procurement methods. However a general reluctance to adopt alternative procurement methods has previously been observed by many researches. They further have suggested that the reluctance is fuelled by the government policies. Hence this paper synthesizes the preliminary findings, providing a logical picture on the effect of government policies as a barrier to adopt alternative procurement methods and how far the current policies would help to popularize less popular procurement methods.

Keywords: *Alternative Procurement Methods, Barriers, Facilitators, Government Policies, Sri Lanka.*

1. INTRODUCTION

Construction industry encompasses a high complexity due to the involvement of many stakeholders, long project durations and the complex contractual relationships which contributes significantly in the development process in both development and developing countries. Therefore, stipulation in adopting a proper procurement method is vital as it leads to the success of a building project. While project success is perceived from widely different perspectives, sustainability has been increasingly recognized as a key parameter. The freedom to choose a procurement method will therefore significantly affect the sustainability of the project delivery process and the operation of the building as well.

Compared to other countries usage of conventional procurement methods in Sri Lankan construction industry is greater than the practice of alternative procurement methods. Shiyamani *et al.* (2005) stated that, the current review of the trends of project procurement systems used in Sri Lanka disclose that the Measure and Pay is the popular procurement method followed by Design and Build. Consequently the usage of alternative procurement system is underprivileged compared to other developing countries. Government, being the largest client and the regulator of the industry, is often thought of having significantly influenced the selection of procurement methods. If this is in fact true, it would be undesirable because various procurement methods have been developed to fulfil varying requirements of project stakeholders. Therefore, a research is a study was imitated to explore whether the government policies and regulations hinder adoption of alternative procurement methods. This paper presents its initial findings through a literature synthesis.

2. INTRODUCTION TO PROCUREMENT SYSTEMS

According to Wibowo (2010) construction industry contributes significantly in terms of scale and share in the development process for both developed and developing countries. The construction

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products provide the necessary public infrastructure and private physical structures for many productive activities such as services, commerce, utilities and other industries. Moreover Oyegoke *et al.* (2009) stated that construction project is a complex process that involves many stakeholders, long project durations and complex contractual relationships. Hence adopting a congruent procurement method will achieve the success of a construction project.

Dewage (2009) simply defines the procedure adopted to procure construction work is regarded as the procurement method of any construction project. Rashid *et al*. (2006) contended that, "The procurement of construction project is vast in scope since it involves the gathering and organizing of myriads of separate individuals, firms and companies to design manage and build construction products, building constructions and civil constructions". In recent years construction procurement has been subject to considerable transformation from lowest cost to best value procurement and a revised agenda for delivering broader policy goals related to social and environmental sustainability (Oyegoke *et al*., 2009). Tookey *et al*. (2001) stated that procurement is, therefore, a succession of 'calculated risks'. Current research considers procurement as a set of rationalistic decisions within a closed environment, aiming to produce generic, prescriptive rules for clients and advisers to use to select the 'best' procurement route for their project. They further stated that reducing procurement risk can be done through better procurement-system.

Moreover Mathonsi and Thawala (2012) argued that, "Procurement systems are vital in ensuring the successful implementation of a construction project, precisely executed for all phases of any particular project".

Due to the various needs of clients different procurement methods are introduced. As Dewage (2009) stated, the well known main procurement methods that have been used at the present time in the construction industry are traditional method, design and Build method, management contracting method and construction Management method.

2.1. CONSTRUCTION PROCUREMENT SYSTEMS USABLE IN SRI LANKA

Separated Procurement Systems

In this method there is clear rigid separation of design and the construction. Normally in this method construction started after the design is completed. In this method client first appoint a consultant to do the design. After designing is fully completed tendering procedure is being held and a contractor is selected to carry out the project (Ashworth, 1996).

Integrated Procurement Systems

In an integrated system the design and the construction clearly integrated each other. In this method normally construction started while the design is ongoing. The contractor enters into separate agreements with consultants, to complete the project according to agreement.

- Design and Build – Here it is contractor's responsibility to do the construction as well as the full design according to the requirements of the client. This method is very popular when a competitive design wanted (Ashworth, 1996).
- Package deal – This is used only in special type of design build project where the employer chooses a suitable design from a given catalogue (Ashworth, 1996).
- Turn Key – In a turnkey project contractor provides all the necessary resources required to carry out the project, including the design, construction as well as the finance (Bagnall, 1999).
- Develop & Construct - Consultants appointed to design the building to a certain stage and then constructors complete and guarantee the design and competition, either using client's consultants or their own designers (Seeley, 1997).

- Private Finance Initiative (PFI) – A system whereby the private sector (usually as a consortium) undertakes to finance the total procurement process on behalf of the public sector, payment being delayed until the project is complete and ready for occupation at handover (Bagnall, 1999).

Management Oriented Systems

The major difference in this system is, adding a new separate management layer in to the design and construction. In this procuring system all the managing function s are carried out by that management layer. This is a good improvement of the separated model (Rameezdeen and De Silva, 2002).

- Management Contracting – An expert builder is appointed on a fee basis well before work starts on the site to advice the design team (Potter, 1995).
- Construction Management – A construction expert is appointed early on, for a fee, to manage the construction process (Potter, 1995).

Collaborative Systems

The basic principle of these systems is the collaboration between two or more parties to achieve successful project objectives through fair dealings, commitment and shared investment (Bagnall, 1999). Partnering is one of possible collaborative system.

- Partnering - Partnering is a technique, which attempt to create an effective project management process between two or more organizations. It aims at generating an organizational environment of trust, open communication and employee involvement and whereby quality and efficiency are continuously improved and both parties derive economic advantage (Bagnall, 1999).
- Joint Venture - The unusual step beyond partnering is the joint venture contract between a major client and providers of the facility; perhaps where co operation is vital. A 51% majority shareholding in the joint company or undertaking provides controlling ownership for one of the partners however depending on the circumstances other proportions are possible (Harris and McCaffer, 2001).

3. PROCUREMENT METHODS PRACTICE IN SRI LANKAN CONSTRUCTION INDUSTRY

The studies of Joseph and Jayasena (2008) shows that some researches shown that in Sri Lanka the traditional procurement system is dominating the procurement market over the years and Design and Build procurement system use as next alternative option among alternative procurement systems however less in practice. What they had synthesized from the contemporary literature is given in Table 1.

Table 1: Trend in methods of procurement in Sri Lanka (source: Joseph and Jayasena, 2008)

% of use(Average) / **Procurement system**	**1977-1981**	**1982-1986**	**1987-1991**	**1992-1996**	**1997-2000**	**2001-2003**
Measure and pay	55	50	58	50	64	72
Lump sum	12	10	8	7	10	5
Prime cost	10	8	5	4	3	1
Design and build	22	31	28	35	21	22
Management contracting	1	1	1	1	1	0
Joint venture	0	0	0	3	1	0
Total	100	100	100	100	100	100

By using the information in Table 1, procurement methods adopted in Sri Lankan construction projects can be categorized as common and uncommon procurement methods practiced in Sri Lankan context as shown in Figure 1.

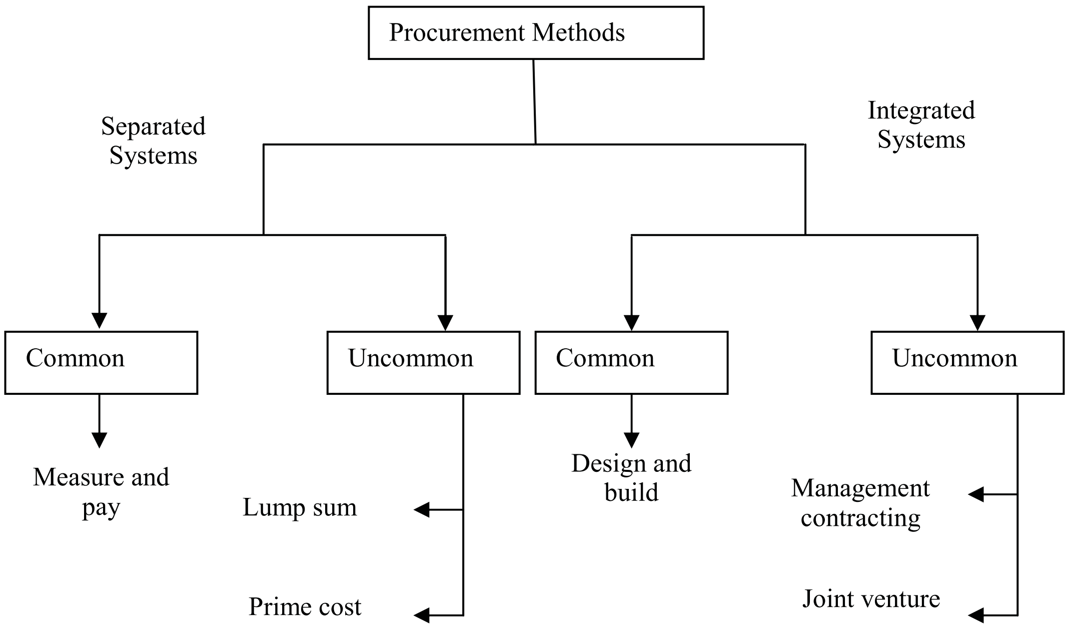

Figure 1: Categorization of Construction Procurement Methods in Sri Lanka

According to Ratnasabapathy and Rameezdeen (2007), in order to assort a condign procurement system, there is a need to distinguish various factors from the internal and external environment in the operational area of the project and industry. Eventhough the majority of public works in Sri Lanka is procured using measure and pay system. There is a reluctance of the public sector to use other non-traditional procurement methods.

4. NEED OF HAVING MANY PROCUREMENT METHODS

Ratnasabapathy and Rameezdeen (2007) reported that, different procurement systems are used for different projects and the precise choice may help to avoid problems and be the key to the attainment of project specific goals. Tookey *et al.* (2001) stated that in today there are number of different types of procurement routes available for clients to choose from which has their own proponents and inherent strengths and weaknesses. Therefore a choosing procurement method is very crucial in construction project. To satisfy the requirement of time completion on time or earlier a plethora of non traditional procurement methods have emerged in the marketplace, which has resulted in design and construction schedules being compressed and construction commencing before the final design is complete (Hanna *et al*. 1999).

Therefore there should be different procurement methods existing to choose the proper one for particular project. According to Love *et al*. (2008) choosing the appropriate procurement system for construction projects is a complex and challenging task for clients particularly when professional advice has not been sought. Eriksson and Westerberg (2010) reported that in recent years there has been an increasing interest in world about the use of partnering in order to improve collaboration among construction project actors. The value that lies in having this model tested is potentially great as the construction literature has many indications that cooperation and collaboration may be a good strategy for achieving project success.

5. FACILITATORS AND BARRIERS FOR ADOPTING NEW PROCUREMENT METHOD.

Selecting a procurement method is a daunting task for the client due to various factors governing a construction project. The most common criteria influencing the choice of procurement method include time, controllable variation, complexity, quality level, price certainty, competition, responsibility, risk avoidance, price completion, government policy and client's familiarity in a procurement method (Hashim *et al*., 2006). Figure 2 outlines the process of selecting best procurement method for a project while Table 2 identifies the facilitators and barriers for each procurement method

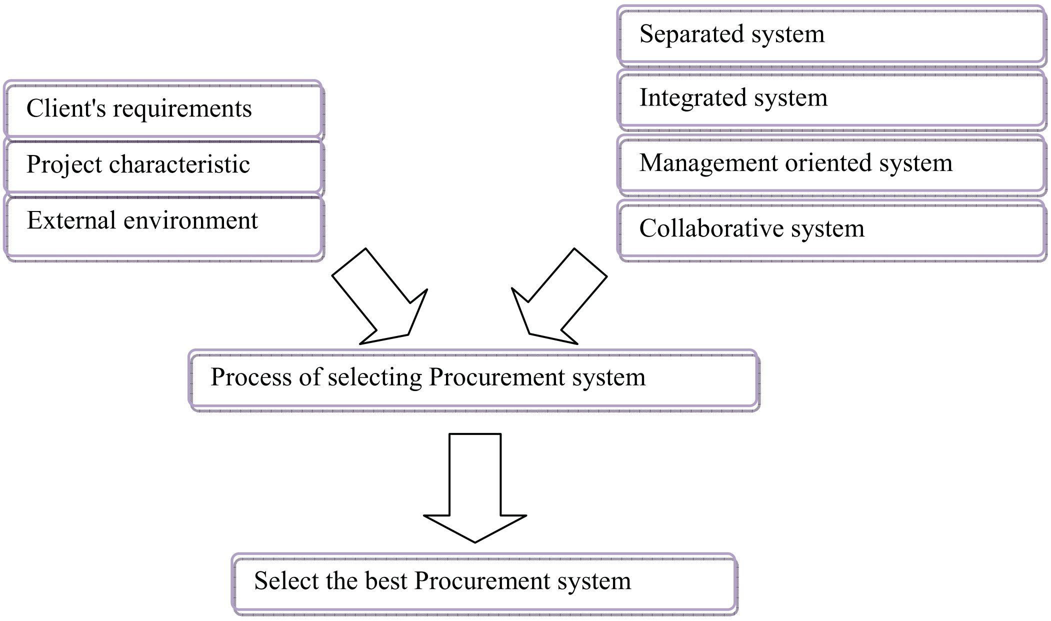

Figure 2: Selection of Best Procurement Method (Source: Ratnasabapathy and Rameezdeen, (2007)

"Non-traditional methods such as design and build and construction management have been advocated as methods for overcoming some of the problems inherent in traditional methods however yet it would appear from these findings that their use is minimal" (Love, 2002).

6. GOVERNMENT ROLE IN CONSTRUCTION INDUSTRY

6.1. MAJOR CLIENT AND REGULATORY BODY IN CONSTRUCTION INDUSTRY

Ofori (1990) specified that, the government is an important participant in the construction industry of every country, playing the role of a major client, regulating authority and the administrator of the development of the industry. Government policies and regulations are very rigid external factors which affect to the construction procurement selection. Hence Hashim *et al*. (2006) argued that, client's choice of procurement method could be affected by various government policies. This could be seen where the clients have to follow government procedure in choosing a particular procurement rout to construction project.

6.2. INFLUENCE OF GOVERNMENT ON PROCURING CONSTRUCTION PROJECT

Rameezdeen and De Silva (2002) critique that, in Sri Lanka, the majorities of public works are procured using measure and pay system. Furthermore Rameezdeen and De Silva (2002) stated that the above reluctance is due to the bureaucratic barrier created by financial regulations and administration regulations of the country.

Joseph and Jayasena (2008) reported that Government contribution in promoting Design and Build in Sri Lanka is very less state that is the number one reason. Very less contribution is given by the Ministry of Finance to the development of Design and Build procurement system as a regulatory body of Sri Lanka. It is found that the very less government contribution in developing Design and Build is the first most significant impediment to the development of Design and Build procurement system in Sri Lanka. In Sri Lankan context, the traditional procurement system is widely used for both private and public projects up to now, since the government and regulatory bodies promoting the traditional procurement method and widely use in public project procurement.

Table 2: Facilitators and Barriers Procurement Systems (Sources: APUC Guidelines, 2008; Love, 2002; Kumaraswamy and Dulaimi, 2001; Joseph and Jayasena, 2008)

Procurement system	**Facilitators**	**Barriers**
Separated systems	Client can control and maintain quality and specifications. Cost certainty. Direct contractual relationship with consultants and main contractor. Standard contract conditions available.	Clients' risk is high. Restrict cost controlling during construction works. Longer time scale.
Integrated systems	Shorter time scale. Clients' risk is low. Cost certainty. Standard contract conditions available.	Client is not allowed to do changes in designs. Clients' requirements are fully detailed before signing the contract. Support with negotiated tendering.
Management oriented systems	Client has the fully control of time. Shorter time scale. Client can manage controllable variations.	Client risk is high. No cost certainty. Lack of standard contract conditions.
Collaborative systems	Win win method. Suit for large scale projects.	Lack of standard contract conditions. Lack of awareness in construction industry.

6.3. *INFLUENCE OF GOVERNMENT ON CONSTRUCTION PROCUREMENT IN SRI LANKAN CONTEXT*

In every country construction contractors are subjected to different standards set by government institutions. In Sri Lanka all contracting firms require a licence to legally perform in the industry. National Construction Association of Sri Lanka (NCASL) and Institute of Construction Training And Development (ICTAD are the institutions who formulate standards for the construction industry. (Dheeran, 2009)

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6.4. EFFORT FROM REGULATORY BODIES IN SRI LANKA ON CONSTRUCTION PROCUREMENT

The National Procurement Agency (NPA) is the principal authority for formulating and effecting amendments to these Guidelines; issuance of manuals, SBDs, evaluation methodologies, standard contracts, and specifications. Any clarification of the provisions of these Guidelines or the aforementioned documents may be sought from the NPA. (NPA guidelines, 2006)

According to Rameezdeen and De Silva (2002) Economic growth has favoured some of the alternative methods to emerge in Sri Lanka. Design and Build is one such method developed mainly due to the industrial growth of the country. The dominance of separated procurement systems in Sri Lanka because to government influence on the construction industry of Sri Lanka. Moreover the government as a major client and the regulator neglected and created a barrier for the development of alternative procurement methods. The construction regulatory agency in Sri Lanka, the Institute for Construction Training and Development (ICTAD) has only considered measure and pay until recently in developing guidelines for the industry. Very little effort was made by the ICTAD to promote other procurement methods in Sri Lanka. Only in 2001 ICTAD published a guideline called "Standard Bidding Document for Procurement of Works Design and Build Contracts". This is the first guideline to be published by the ICTAD for an alternative procurement arrangement. This has further strengthened the hold of measure and pay as the dominant procurement method in Sri Lanka.

Government is a major external party which influences the construction industry of any country. Therefore it is obvious that there is a reluctant in practice of alternative procurement methods in Sri Lankan context and there is an influence of government when adopting alternative procurement methods.

7. CONCLUSIONS

In Sri Lankan construction industry few number of procurement methods are used. Even though there are many problems occurred with conventional procurement methods, alternative procurement methods are hardly appeared in Sri Lankan context. According to literature, Government of every country plays an important and major role in construction industry as the major client and the major regulating authority. As a major regulating authority government has introduced polices and regulations which affected to the construction industry. Therefore, government policies and regulations on construction industry are likely to significantly affect the adoption of alternative procurement methods.

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IMPACT OF MAINTENANCE MANAGEMENT PROCEDURES ON ENERGY EFFICIENCY OF CHILLERS

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ABSTRACT

The most important element of the central air conditioning system, the chiller, accounts for about 40% of annual total energy consumption of commercial and industrial buildings. As a result, many approaches have been proposed to increase energy efficiency of chillers with the intention of managing the annual total energy consumption of facilities. Among them, it was revealed that the approach of proper chiller maintenance procedures lead towards the energy efficiency of chillers. Therefore, the research was focused on identifying the impact of maintenance management procedures on energy efficiency of chillers.

The data was collected through a pilot survey and a main survey which were followed by a questionnaire along with observations and interviews with experienced industry practitioners.

It was identified that the maintenance procedures has a great impact towards the energy efficiency of chillers. Perform condenser water quality test, Monitoring refrigerant pressure and temperature, Monitoring water flows, cleaning of condenser bundle and cooling tower cleaning and water treatment were identified as the most significant maintenance activities which assist to meet the standard energy efficiency level of chillers. Eventually, a multiple linear regression model was developed with the intention of deriving relationship between performance deviation of above maintenance activities and energy efficiency drop of chillers.

Keywords: *Chillers; Energy Efficiency; Energy Efficiency Drop; Maintenance Management Procedures; Maintenance Performance Deviation.*

1. INTRODUCTION

As a rule of thumb, the air conditioning systems used in commercial and institutional buildings can account for more than 50% of the total electricity consumption (Jayamaha, 2007). Thereof, Chan et al. (2009) states that the most important part of a central air conditioning system, the chiller accounts for more than 60% of power consumption of central air conditioning system. Further, it is proved by Lee and Lee (2010) in a recent article indicating that chillers alone may already account up to 35-40% of annual electricity consumption. By analysing above data, it can be argued that the chiller of any air conditioning system approximately compensates 30% of total energy consumption of a facility and it creates a considerable necessity to pay attention on achieving the energy efficiency of chillers.

Therefore, this research was focused on identifying the impact of maintenance procedures towards achieving the energy efficiency of chillers and it was limited to the chiller plants of five star hotels in Colombo metropolitan area.

2. FACTORS AFFECTING THE ENERGY EFFICIENCY OF CHILLERS

Efficiency of a chiller is measured by how many units of power are used to produce one unit of cooling (Jayamaha, 2007).

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$$Chiller\ Efficiency = \frac{Power\ Input(kW)}{Cooling\ Produced\ (RT)} \qquad \text{(Eq:01)}$$

However, it is evident in the literature that several factors can be affected the energy efficiency of chillers. Chan (2004 cited Chan *et al.,* 2009) reveals seven such factors namely partial load condition, external environment condition, chilled water flow, chilled water supply temperature, condensation super cooling, evaporation superheating, and preset compressor temperature. Partial load condition is one of them, which has a greater impact on efficiency of chillers (Yu and Chan, 2009). It is proved by Yu and Chan (2009) that, when the cooling load of a building is changed throughout its occupied period, chillers tend to operate frequently at part load and this kind of operation will cause chiller efficiency to drop and such drop becomes considerable when the set point of condensing temperature is fixed at a high level while outdoor temperature is low. Variation of weather condition (external air temperature and relative humidity) is the other factor which strongly influence on efficiency of chiller (Yu and Chan, 2005). In an article, Yu and Chan (2007), has proved it by stating that'impact of weather and external environment condition (external air temperature and relative humidity) affect the energy efficiency of chillers through fluctuating the cooling load'.

Further, with the improvements of the design of chillers, Jayamaha (2007) expresses that efficiency of chillers have been improved and it is about averagely 44% over the period of last 30 years. Therefore, it can be argued that design of chillers also affect the efficiency of chillers.

Chiller maintenance is another factor which affects the energy efficiency of chillers. That is proved by Lewis and Riley (2011) stating that 'proper maintenance is necessary to achieve optimal energy performance, while energy performance data is needed for effective maintenance management'. Accordingly, in next section it is focused on what kind of maintenance procedures have been introduced by various organizations in order to achieve the efficiency of chillers.

3. MAINTENANCE OF CHILLERS

As it is discussed earlier, chiller maintenance has a great impact on its efficiency. Therefore, many organizations have introduced various chiller maintenance procedures based on various categories. For instance, American Society of Heating Refrigeration and Air- conditioning Engineers (ASHRAE) (2004) introduces two chiller maintenance procedures based on two categories in ASHRAE Handbook-HVAC Systems and Equipment. One is based on components of the chiller namely compressor, condenser and evaporator and other one is on types of maintenance namely continual monitoring, periodic checks, regularly scheduled maintenance and extended maintenance checks. In addition to that, U.S Department of Energy (2010) has also introduced a list of recommended maintenance procedures for chiller maintenance. Furthermore, recommended maintenance procedures published by McQuay International (2005) and Trane Inc (2005) can be shown as two examples for maintenance procedures introduced by chiller manufactures for chiller maintenance.

4. RESEARCH METHODOLOGY

A comprehensive literature survey was carried out referring to journals, books and other published documents to obtain existing knowledge on factors affecting energy efficiency, maintenance procedures of chillers, and the researchable gaps towards the relationship between the maintenance management procedures and energy efficiency of chillers,.

Through a pilot survey which was carried out among industrial specialists (air conditioning consultants), the factors affecting energy efficiency of chillers which were discovered through past literature were assessed and established. And further, it was prioritized the identified 31 maintenance activities towards the energy efficiency of chillersthroughalikert scale questionnaire consisted with 1-5 rating scalewhere, 1 = very little important, 2 = little important, 3 = average important, 4 = high important, 5 = extremely important. As the number of well experienced and well expertise air conditioning consultants engage with chiller systems are hardly found, 4 numbers of air conditioning consultants were selected as sample of specialists for the pilot survey.

The practicing level of the identified 31 maintenance activities (PLMA) of chillers and current energy efficiency of chillers were identified through the main survey.The practicing levels of chillersalso were recognized using a likert scale questionnairewhere the rating scale is similar as above and current energy efficiency of chillers were identified through interviews and observations of past records.The survey sample was established based on number of the chillers operate in Colombo city hotels. Accordingly, 14 chillers in 07 five star hotels were selected as the sample for the main survey which was deemed to be the target population of the study.

Statistical tests using Statistical Package for Social Sciences (SPSS) software were carried out to analyse the data. Further, multiple regression modelling was used to establish a relationship between energy efficiency (dependent variable) and maintenance activities (independent variables) of chillers.

5. MULTIPLE REGRESSION MODEL

Generally, regression modeling is used to examine the relationship or the behavior of the dependent variable with response to two or more independent variables (Rice, 1995). Accordingly, in this research, a multiple regression model was developed to establish the relationship between the deviation of performance level of required maintenance activities and resultant energy efficiency drop of chillers.

5.1. INPUT OF THE MULTIPLE REGRESSION MODEL

Maintenance Performance Deviations (MPD) of the identified maintenance activities were used as inputs (independent variables) to capture the efficiency loss caused to these deviations due to lack of implementation of such required maintenance activities of chillers. MPD is derived based on the difference between the recommended importance level of maintenance activities of chillers and their current practicing level. MPD was established using the equation 02 as follows.

$$MPD = \frac{ILMA \times (5 - PLMA)}{ILMA \times 5} \times 100 \qquad \text{(Eq: 02)}$$

Where, $ILMA$= importance level of maintenance activities and $PLMA$= the practicing level of maintenance activities.

The importance level (ILMA) and the practicing level (PLMA) of identified maintenance activities were quantified using the mean ratings of respondents' views which were obtained according to the given 1-5 likert scale. Eight (08) maintenance activities were established as significant from the identified 31 activities (Refer Table1). Table 1, 2 and 3 show ILMA, PLMA and MPD values of these maintenance activities respectively.

Table 1: Significant Maintenance Activities and Their ILMA

Significant Maintenance Activities	Abbreviation	Importance Level of Maintenance Activities (ILMA)
Monitor for condenser tube fouling	MCTF	4.25
Perform condenser water quality test	PCWQT	5.00
Operating conditions logging	OCL	5.00
Monitoring refrigerant pressure and temperature	MRPT	4.75
Monitoring water flows	MWF	5.00
Monitoring water pressure and temperature	MWPT	5.00
Cleaning of condenser bundle	CCB	5.00
Cooling tower cleaning & water treatment	CTCWT	5.00

Table 2: Performance Level of Maintenance Activities

CN	MCTF	PCWQT	OCL	MRPT	MWF	MWPT	CCB	CTCWT
C1	100	20	0	20	0	0	20	20
C2	100	20	0	20	0	0	20	20
C3	100	40	0	40	40	0	40	40
C4	100	40	0	40	40	0	40	40
C5	100	100	0	40	40	0	100	100
C6	100	20	0	20	0	0	40	20
C7	100	20	0	20	0	0	40	20
C8	100	100	0	40	40	0	100	100
C9	100	100	0	40	40	0	100	100
C10	100	40	0	40	40	0	100	40
C11	100	40	0	40	40	0	100	40
C12	100	20	0	20	0	0	20	20
C13	100	20	0	20	0	0	20	20
C14	100	20	0	20	0	0	20	20

Table 3: Performance Deviation Level of Maintenance Activities

CN	MCTF	PCWQT	OCL	MRPT	MWF	MWPT	CCB	CTCWT
C1	100	20	0	20	0	0	20	20
C2	100	20	0	20	0	0	20	20
C3	100	40	0	40	40	0	40	40
C4	100	40	0	40	40	0	40	40
C5	100	100	0	40	40	0	100	100
C6	100	20	0	20	0	0	40	20
C7	100	20	0	20	0	0	40	20
C8	100	100	0	40	40	0	100	100
C9	100	100	0	40	40	0	100	100
C10	100	40	0	40	40	0	100	40
C11	100	40	0	40	40	0	100	40
C12	100	20	0	20	0	0	20	20
C13	100	20	0	20	0	0	20	20
C14	100	20	0	20	0	0	20	20

5.2. OUTPUT OF THE MULTIPLE REGRESSION MODEL

As the model was focusing on the Energy Efficiency Drop (EED) of chillers with response to the maintenance performance deviation of maintenance activities, EED was considered as the output of the model (dependent variable). Therefore, the percentage EED was calculated based on the equation 3 as follows.

$$EED = \left(\frac{SEE - EEE}{SEE} \right) \times 100 \qquad \text{(Eq: 03)}$$

Where, SEE = the standard energy efficiency and EEE = the existing energy efficiency

In order to derive the EED of each chiller, standard efficiency of each chiller was taken referring to the chiller manuals, catalogues and chiller name plates during the field observation of the main survey. The existing energy efficiency was calculated using the Equation 01 in Section 02 by using the energy consumption data obtained from the field observation during the main survey.

5.3. MULTIPLE REGRESSION MODEL

The model can be mathematically expressed as,

$$Y_i = B_0 + B_i \times X_i + \dots\dots\dots.. + B_k \times X_k + e \qquad \text{(Eq:04)}$$

Where, B_0 = coefficient, Bi = the coefficient of i thvariable, $X_i \forall I$=1,,,, 8 = identified maintenance activities (refer Table 1), B_k = the coefficient of k^{th} maintenance activity, and e = the error term.

6. RELATIONSHIP BETWEEN MPD LEVEL AND EED

MPD levels derived in Table 3 and EED which was calculated according to Equation 3 can be shown as a summery in Table 4 which used for the development of multiple linear regression model.

Table 4: Maintenance Performance Deviation Level and Energy Efficiency Drop

CN	Maintenance Performance Deviation								EED
	MCTF	PCWQT	OCL	MRPT	MWF	MWPT	CCB	CTCWT	
C1	100	20	0	20	0	0	20	20	3.9
C2	100	20	0	20	0	0	20	20	3.6
C3	100	40	0	40	40	0	40	40	11.5
C4	100	40	0	40	40	0	40	40	15.9
C5	100	100	0	40	40	0	100	100	26.9
C6	100	20	0	20	0	0	40	20	8.3
C7	100	20	0	20	0	0	40	20	5.2
C8	100	100	0	40	40	0	100	100	33.8
C9	100	100	0	40	40	0	100	100	24.6
C10	100	40	0	40	40	0	100	40	13.4
C11	100	40	0	40	40	0	100	40	23.8
C12	100	20	0	20	0	0	20	20	7.9
C13	100	20	0	20	0	0	20	20	5.6
C14	100	20	0	20	0	0	20	20	4.6

Correlations of performance deviation of each maintenance activity with the dependent variable were calculated and correlation coefficients were derived (refer Table 5). They can be used as a prior observation on the dependent variable with respect to changes of each independent variable. It was considered the change of one variable at one time to derive the prospected change in the dependent variable.

Table 5: Correlation between Maintenance Performance Deviation and Energy Efficiency Drop

Maintenance Activities		Correlation Coefficient
Monitor for condenser tube fouling	MCTF	0.000
Perform condenser water quality test	PCWQT	0.910
Operating conditions logging	OCL	0.000
Monitoring refrigerant pressure and temperature	MRPT	0.825
Monitoring water flows	MWF	0.825
Monitoring water pressure and temperature	MWPT	0.000
Cleaning of condenser bundle	CCB	0.880
Cooling tower cleaning & water treatment	CTCWT	0.910

According to the correlation coefficients (refer Table 5), except MCTF, OCL and MWPT, all other maintenance activities showed a positive and strong relationship with the energy efficiency drop of chillers where PCWQT, MRPT, MWF, CCB and CTCWT were statistically significant at 98% confidence level.Since MCTF, OCL and MWPT had zero correlation with the energy drop those maintenance activities were rejected by SPSS from the developing process of the model.

6.1. *IMPACT OF MAINTENANCE ACTIVITIES ON THE ENERGY EFFICIENCY*

The regression model was developed based using the maintenance activities which had a positive relationship with EED (refer Table 5). Accordingly, the developed regression model can be expressed as follows.

$$Y = B_0 + B_{PCWQT} \times MPD_{PCQWT} + B_{MRPT} \times MPD_{MRPT} + B_{MWF} \times MPD_{MWF} + B_{CCB} \times MPD_{CCB} + B_{CTCWT} \times MPD_{CTCWT} + e$$
(Eq: 05)

Assumptions Made in Linear Regression

- $E(e_i) = 0$: The random error terms (e_i) are normally distributed with 0 (zero) mean
- $E(e_i^2) = \sigma_e^2$: The random error has the same variance for all i.
- $E(e_i e_j) = 0$: The random error term must be independent; there is no correlation across observations

Considering above assumptions, the Equation 05 can be re-written as;

$$Y = B_0 + B_{PCWQT} \times MPD_{PCWQT} + B_{MRPT} \times MPD_{MRPT} + B_{MWF} \times MPD_{MWF} + B_{CCB} \times MPD_{CCB} + B_{CTCWT} \times MPD_{CTCWT}$$
(Eq: 06)

Since MCTF, OCL and MWPT had zero correlation with the energy drop and since, PCWQT and MWF having multicollinearity effect with other activities (refer Table 5), those maintenance activities were rejected by the SPSS when calculating coefficient and regression coefficient and three maintenance activities; MRPT,CCB and CTCWT were remained.

6.1.1. *PARAMETERS OF THE REGRESSION MODEL*

COEFFICIENT OF DETERMINATION

In Multiple Linear Regression modeling, coefficient of determination (R^2) is an evaluation of the overall closeness of the relationship between independent variable and dependent variables and it represents the proportion of variation in Y (EED) which could be explained by variation in X_1 to X_5 and how closely data points cluster around the regression line. Accordingly, in this model the R^2 was obtained as 0.902 and it indicates that there is a strong relationship between MPD of MRPT,CCB and CTCWT maintenance activities and EED.

REGRESSION COEFFICIENTS

Coefficient for the constant denotes the intercept of the regression line and it represents the energy efficiency drop of the chiller when all maintenance activities are being done in an optimum way. Regression coefficients derived from the SPSS for the continuation of the model are shown in Table 6.

Table 6: Regression Coefficients of the Model

Variables/Constant		Regression Coefficients
Constant (Intersect)	B_0	-
Monitoring refrigerant pressure and temperature	B_{MRPT}	0.191
Cleaning of condenser bundle	B_{CCB}	0.298
Cooling tower cleaning & water treatment	B_{CTCWT}	0.530

According to the results of Table 6, when all maintenance activities are being done in an optimum way, the efficiency drop is 0.

Coefficients for maintenance performance deviation of each maintenance activity denote the degree of change in energy efficiency drop of chillers with 1% change in performance deviation of each maintenance activity. The results showed, 1% change of performance deviation of MRPT, CCB and CTCWT will impact on the energy efficiency of chillers by 19.1%, 29.8% and 53%.

Therefore, based on regression coefficients as shown in the Table6, the relationship between the MPD and EED of chillers can be illustrated as shown in Equation 07.

$$EED = 0.191 \times MPD_{MRPT} + 0.298 \times MPD_{CCB} + 0.530 \times_{CTCWT} \quad \text{(Eq: 07)}$$

PARTIAL CORRELATION COEFFICIENT

The partial correlations interpret the relationship between dependent variable and each independent variable, when other independent variables are held constant.

Table 7: Partial Correlation

Variables/Constant		**Partial Correlation**	**(Partial Correlation)^2**
Monitoring refrigerant pressure and temperature	B_{MRPT}	0.324	0.105
Cleaning of condenser bundle	B_{CCB}	0.425	0.181
Cooling tower cleaning & water treatment	B_{CTCWT}	0.699	0.489

The analysis of the partial correlations shown in Table 7 proved that; the cooling tower cleaning & water treatment is the most important maintenance activity which leads energy efficiency drop.

PART COEFFICIENT

Table 8: Part Correlations

Variables/Constant		**Part Correlation**	**(Part Correlation)^2**
Monitoring refrigerant pressure and temperature	B_{MRPT}	0.107	0.011
Cleaning of condenser bundle	B_{CCB}	0.147	0.022
Cooling tower cleaning & water treatment	B_{CTCWT}	0.306	0.094

The part correlation interprets the unique contribution of each independent variable by alone to the dependent variable. Accordingly, the analysis of part correlation illustrated in Table 8 proved that cooling tower cleaning & water treatment is the most effectible maintenance activity.

IMPACT TOWARDS EFFICIENCY DROP BY OVERLAPPING MAINTENANCE DEVIATION

The overlapping impact on the energy efficiency by all maintenance activities was derived subtracting the cumulative of squared of part correlations from the coefficient of determination (R^2). Accordingly, the overlapping impact or the jointly contribution of maintenance activities toward the energy efficiency is 75.5% of the variance of the energy efficiency drop (90.2 – (1.1 + 2.2 + 9.4)).

7. APPLICATION OF THE DEVELOPED MODEL

The developed model was applied to derive the energy efficiency drop of chillers in Colombo city hotels. as shown in Table 9 by using maintenance performance deviations and energy efficiency drop which were illustrated in Table 4 and established 3 maintenance activities by the model namely; MRPT, CCB and CTCWT.

Table 9: Average Performance of the Industry

Chiller No.	MPD_{MRPT}	MPD_{CCB}	MPD_{CTCWT}	B_{MRPT}	B_{CCB}	B_{CTCWT}	$Y = EED$
C1	20	20	20	0.191	0.298	0.530	20.38
C2	20	20	20	0.191	0.298	0.530	20.38
C3	40	40	40	0.191	0.298	0.530	40.76
C4	40	40	40	0.191	0.298	0.530	40.76
C5	40	100	100	0.191	0.298	0.530	90.44
C6	20	40	20	0.191	0.298	0.530	26.34
C7	20	40	20	0.191	0.298	0.530	26.34
C8	40	100	100	0.191	0.298	0.530	90.44
C9	40	100	100	0.191	0.298	0.530	90.44
C10	40	100	40	0.191	0.298	0.530	58.64
C11	40	100	40	0.191	0.298	0.530	58.64
C12	20	20	20	0.191	0.298	0.530	20.38
C13	20	20	20	0.191	0.298	0.530	20.38
C14	20	20	20	0.191	0.298	0.530	20.38
Average	**30**	**54.2857**	**42.8571**	**0.191**	**0.298**	**0.530**	**44.6214**

As shown in Table 9, average industrial maintenance performance deviation MRPT, CCB and CTCWT are 30%, 54.28% and 42.85 respectively. And the respective average energy efficiency drop is 44.62% which makes a huge burden on the energy consumption of the hotel industry and on the national energy supply of the country as well.

Thus, it can be stated that when maintenance performance of MRPT, CCB and CTCWT are deviated from the standard maintenance practice by 30%, 54.2857% and 42.8571% respectively, the energy efficiency of the chillers also affects to deviate from the standard energy efficiency by 44.62% negatively.

8. CONCLUSIONS

Among the factors that affecting the energy efficiency of chillers, maintenance was identified as one of the significant factors which has a great impact on efficiency of chillers. Similarly, among 31 identified important maintenance activities, 08 activities were established as significant for chillers based on the mean ratings. They were Monitoring for condenser tube fouling, Performing condenser water quality test, Operating conditions logging, Monitoring refrigerant pressure and temperature, Monitoring water flows, Monitoring water pressure and temperature, Cleaning of condenser bundle and Cooling tower cleaning & water treatment were selected as the most influencing maintenance activities.

In order to derive the relationship between the maintenance activities and energy efficiency, performance deviation of each maintenance activity for each chiller as the independent variables and respective energy efficiency drop (EED) of each chiller as the dependent variable, were considered to develop the multiple regression model.

Monitoring for condenser tube fouling, Operating conditions logging and Monitoring of water pressure and temperature were rejected from the regression model due to their zero stand deviation and further perform condenser water quality test and Monitoring water flows were removed due to their multicollinearity with others factors. Thus, EED was dependent with three maintenance activities such as Monitoring refrigerant pressure and temperature (MRPT), Cleaning of condenser bundle (CCB) and Cooling tower cleaning & water treatment (CTCWT). It was observed that MRPT, CCB and CTCWT are deviated from the standard maintenance practice by 30%, 54.2857% and 42.8571% respectively, resulting 44.62% drop of energy efficiency of chillers in five star hotels in Colombo city.

Accordingly, the developed model can be used as an influencing tool for industrial practitioners to upgrade their existing chiller maintenance practices and to improve the efficiency performance of their chillers individually. And the model developed using average industrial practices will be a benchmark of the industry to be constructed strategic maintenance practices towards upgrading overall industrial maintenance and energy efficiency performance of chillers.

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IMPORTANCE OF OCCUPANTS' EXPECTATIONS FOR ACCEPTANCE OF GREEN BUILDINGS: A LITERATURE REVIEW

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ABSTRACT

The buildings, where people live, work, and protect people from nature's extremes, yet they also affect human health and environment in countless ways. The increasing consensus on climate change has resulted in escalating demands on the public to make better environmental choices in building construction. The term 'green design' has been used fairly consistently over the past decade to emphasize such environmental performance of buildings. Many studies have found that the construction clients are demanding assurance of their buildings' long-term economic and environmental performance and costs. Further, the occupants have been favourably disposed to green buildings from their conventional environments. Moreover, in the early stages of a transition towards sustainability, the priorities placed on environmental issues are subscribed by society as a whole and those implicit in building owner's priorities and expectations. Hence, the modern practice has extended and complemented the conventional building construction process to achieve sustainable or high performance building. Accordingly, key research papers were reviewed in this research paper in order to identify occupants' expectations and its importance for the acceptance of green building. Literature stated that there is more potential to change the existing buildings to be more 'green', as the quality of built environment is a major expectation of building occupants. Further, most of the occupants expect quality indoor environment with properly controlled and maintained temperature, humidity, noise, lighting and thermal comfort parameters within buildings. It is due to the certainty of reaching their expectations specially to obtain comfortable working environment. Hence, it implies that the occupants' expectations are significance for the acceptance of any green building specially in moving from their typical working environments. The reason is that the poor fit between the built environment and the needs and expectations of the occupants may lead to dissatisfaction, health issues and productivity losses.

Keywords: *Building Occupants; Expectations; Green Building; Indoor Environment Quality; Acceptance.*

1. INTRODUCTION

The buildings, where people live, work, and protect people from nature's extremes, yet they also affect human health and environment in countless ways. The increasing consensus on climate change has resulted in escalating demands on the public to make better environmental choices in building construction. It is widely recognized that the current environmental crisis is a human problem and solutions depend on major changes in human attitudes, expectations and actions (Cole, 2010). The term 'green design' has been used fairly consistently over the past decade to emphasize such environmental performance of buildings fit with human expectations and actions. Further, Green Building (GB) has emerged as a new building philosophy, encouraging the use of more environmentally friendly materials, the implementation of techniques to save resources and reduce waste consumption, and the improvement of indoor environmental quality, among others in order to mitigate the impact of buildings along their life cycle (Thormark, 2006 cited Lacouture *et al*., 2008). Lacouture *et al*., (2008) further verified that the green building design would result in environmental, financial, economic, and social benefits. Green building occupants despite an increasing interest in the green building investment.

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Many researchers suggest that green building users were more forgiving of their building, which has important implications to green building design and evaluation. It has been previously argued that in order for green buildings to perform effectively in the context of a low-carbon future, a shift is required from conceptualizing the occupant as a passive recipient, to the inhabitant who may play a more active role in achieving comfort and satisfaction (Cole, 2010). It is encouraging to see green building users' capability and potentiality to balance the good features against the bad to reach their overall comfort when they are provided with control over the physical environment.

However, there were no studies more focusing on green buildings and their impact on occupants expectations. Much of the emphasis to date in green building development has been on optimizing energy and resource efficiency. Very little was known about user perception and satisfaction in green buildings (Lau *et al*., 2013). The demand and willingness of clients eventually determines the development of sustainable or green buildings (Hakkinen & Belloni, 2011). Therefore, this study is expected to identify occupants' expectations of green buildings and to convince its importance for acceptance of green buildings.

2. LITERATURE REVIEW

2.1. GREEN BUILDINGS

The indoor environment is where people spend 90% of their time (Kosonen and Tan, 2004). Hence, the occupant exposure to microbial, chemical and building-physical factors in indoor environments can lead to a series of health symptoms ranging from discomfort to clinical disease (EPA, 1995 cited Prakash, 2005). Further, this is incorporated in the human right to a healthy indoor environment as formulated in the WHO 1985 Constitution (Kosonen and Tan, 2004). Consequently, enhancing the quality of indoor environment highly concerns in recent years.

Thormark, (2006 cited Lacouture *et al*., 2008) verified that GB has emerged as a new building philosophy, encouraging the use of more environmentally friendly materials, and implementation of techniques to save resources and specially the improvement of indoor environmental quality, among others. Henceforth, GB 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, or sustainable building, is the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition (EPA GB, 2008 cited Edwin *et al*., 2009). 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).

As a study by Cheng (2007) mentioned that the concept of GB has applied in most of the countries as to reduce the impact of buildings on environment and human health. As Cheng further stated that Green Building" is called "Environmental Co-Habitual Architecture" in Japan, "Ecological Building" or "Sustainable Building" in Europe and "Green Building in North American countries. Many fashionable terms such as "Green consumption", "Green living", "Green illumination" have been broadly used. In Taiwan, currently, "Green" has been used as a symbol of environmental protection in the country. According to studies by Lacouture *et al*. (2008) and Karkanias *et al*. (2010), other benefits of bioclimatic or green buildings include lower energy and operational costs, market advantages for the building developer, higher indoor environmental quality and therefore living quality or higher productivity and lower long-term exposure to environmental or health endangering factors thus, it reduces health cost. Consequently, a recent trend toward increased concern about the impacts of buildings on the larger environment has led many building design professionals to design so-called "sustainable architecture" or "green buildings" (Levin, 1995).

2.2. *MOVING GREEN FROM NON-GREEN*

Under the category of Indoor Environmental Quality (IEQ) in the LEED checklist, IEQ comprises of indoor air quality (IAQ), including, environment tobacco smoke, Carbon dioxide monitoring, indoor chemical and pollutant source, thermal comfort, and daylight and views. According to a study by Levin (1995), among the other indoor environmental factors that must be considered are the quality of thermal, light, acoustic, privacy, security, and functional suitability.

Green Building Council showed that many of its members believed that sustainable or green building design would become a more common practice once the human benefits had been identified (Heerwagen, 2000 cited Lacouture *et al*., 2008). Noticeably, human benefits should become a hot spot of research on green buildings; occupant comfort and satisfaction which lay the foundation for a healthy and productive building, therefore, should be investigated (Lau *et al*., 2013).

Other benefits of GBs related to indoor environmental quality improvements are the reduction on health costs and the increase on employees' productivity (Ross & Lopez-Alcala, 2006 cited Lacouture *et al*., 2008) through their perceived satisfaction towards work areas (Ries *et al*., 2006 cited Lacouture *et al*., 2008). While a considerable amount of this engagement is directed at technical performance metrics such as energy use, greenhouse gas emissions, water use, etc necessary to guide positive decision-making and action, interest is also growing with respect to understanding the quality of experience that buildings afford their users (Cole, 2010). It is widely believed that occupants prefer a high degree of adaptive opportunities, as can be provided within naturally ventilated (NV) buildings as opposed to centrally controlled air conditioned (AC) designs. Many studies have found occupants are more favourably disposed to green buildings than their conventional energy-intensive predecessors (Leaman & Bordass, 2007 cited Deuble & Dear, 2012). It is widely believed that green buildings are more comfortable than conventional buildings; thereby making them more satisfying and productive workplaces, there is little empirical evidence to support this belief (Paul & Taylor, 2007).

2.3. *OCCUPANTS' EXPECTATIONS OF GREEN BUILDINGS*

Numerous studies have explored how building users perceive the indoor environment and which conditions are considered to be comfortable (Frontczak & Wargocki, 2010). For all actors involved with planning, developing and managing buildings, the environmental impact relating to energy use and the quality of the indoor environment are both aspects of major concern. However, many studies stated that high quality indoor environment is the major expectation of building occupants as it is directly affected on their health, well-being and the productivity. Much of the emphasis to date in green building development has been on optimizing energy and resource efficiency. However, green buildings need to do more than effectively use natural resources within economic means (Lau *et al*., 2013).

It is crucial that a reduction in the environmental impact of a building is not achieved through compromising the indoor environment. They must also support the comfort and well-being of their occupants. Very little was known about user perception and satisfaction in green buildings (Lau *et al*., 2013). The environmental impact relating to energy use and the qualities of the indoor environment are two of the most significant environmental aspects relating to buildings. To some extent these are interconnected since for example lower energy use for heating, which normally means less environmental impact, may cause discomfort for the users. It is thus crucial that a reduction in the environmental impact of a building is not achieved by lowering the quality of the indoor environment (Malmqvist, & Glaumann, 2006, 2009). In standard sealed buildings, heating, ventilation and air-conditioning (HVAC) systems are often sized and operated to maintain indoor conditions within a narrow range of temperatures and humidity. In many places, comfort expectations have evolved to leave little margin for error in this regard Borgeson & Brager, 2011). Hence, to ensure continued growth in the adoption of green building technologies it is important to ensure that customer needs are being addressed and that claims of performance are warranted; this means evaluating the performance and life-cycle costs of new green buildings as they come on line. The particular import to corporate customers in green buildings is the indoor environmental quality (usually measured in terms of occupant comfort) of a building because there is evidence that links comfort to satisfaction and productivity (Paul & Taylor, 2007). Building users will often employ a wide range of passive cooling strategies and adaptive opportunities available to them expecting their own comfort conditions to suit their needs (Deuble & Dear 2012).

2.4. INDOOR ENVIRONMENTAL QUALITY IN GREEN BUILDINGS

The indoor environment is where people spend 90% of their time (Kosonen and Tan, 2004). Hence, the occupant exposure to microbial, chemical and building-physical factors in indoor environments can lead to a series of health symptoms ranging from discomfort to clinical disease (EPA, 1995 cited Prakash, 2005) Further, this is incorporated in the human right to a healthy indoor environment as formulated in the WHO 1985 Constitution (Kosonen and Tan, 2004). Consequently, enhancing the quality of indoor environment highly concerns in recent years. The term Indoor Environmental quality (IEQ) is referring to “the environmental qualities within a building, used especially in relation to the health and comfort of building occupants” (Hobday, 2011). Hence, IEQ refers to all aspects of the indoor environment that affect the health and well-being of such occupants (Levin, 1995). According to a studies by Prakash (2005), Portman *et al*. (2006 cited Lee *et al*., 2009) and Lee (2010), IEQ is one of five categories of the LEED (Leadership in Energy and Environmental Design) building assessment system, developed by the Green Building Council of the United States of America including sustainable site, energy and atmosphere, water efficiency, materials and resources, and indoor environmental quality.

Under the category of IEQ in the LEED checklist, IEQ comprises of indoor air quality (IAQ), including, environment tobacco smoke, Carbon dioxide monitoring, indoor chemical and pollutant source, thermal comfort, and daylight and views. According to a study by Levin (1995), among the other indoor environmental factors that must be considered are the quality of thermal, light, acoustic, privacy, security, and functional suitability. Henceforth, IEQ generally encompasses factors such as temperature, humidity, ventilation, indoor air quality, day lighting and lighting quality, thermal comfort and access to views.

Green building parameters to ensure occupants’ IEQ expectations

Once the evaluation and assessment of environmental impact of a building is carried out before it is built and when only the representation of the building is available, environmental impacts from that building could be prevented. Hence, IEQ is a major concern in developing such green assessment tools due to its considerable impact on wellbeing of the building occupants. Thus, most of green assessment tools specially LEED Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) and Green Star techniques have developed considering the IEQ as a major criteria towards sustainable buildings (Boonstra and Pettersen, 2003; McKay, 2007).

According to the Table 1, IEQ is a major concern in developing such green assessment tools due to its considerable impact on wellbeing of the building occupants. Hence, many IEQ parameters have concerned in these green assessment tools to fulfil IEQ requirements in green buildings. These parameters can be applied in order to control temperature and humidity such as, room temperature settings, zone and system control, using low emitting materials etc while sound insulation, absorption materials, equipment noise controlling strategies are applied to ensure acoustic quality in green buildings. Operable windows, air intake, fresh air and ventilation rates can be applied as the suitable parameters for ventilation quality. As the occupants are highly expected, IAQ can be ensured by adapting many green parameters including CO_2 and VOC monitoring and controlling, control of smoking, air change effectiveness, pollutant source controlling and construction IAQ management plan. Further, many parameters can be applied in order to maintain and improve the lighting quality and thermal comfort in green buildings. As most of occupants are expecting quality indoor environment while working in green buildings, the properly controlled IEQ factors ultimately help to execute the expectations of green building occupants.

Table 1: IEQ parameters in green buildings (Boonstra and Pettersen, 2003; Haapio, 2008; Wallhagen, 2010; GBCSL, 2010)

IEQ factor	LEED	BREEAM	Green Star	CASBEE	GREEN^{SL}®
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 & 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 Co2 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
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

2.5. *OCCUPANTS' ACCEPTANCE OF GREEN BUILDINGS IN TERMS OF IEQ EXPECTATIONS*

Occupant acceptance of an indoor environment in green buildings depends on a number of environmental parameters. A number of studies have attempted to understand the quantitative relationship between occupant overall satisfaction and the building's performance on individual IEQ factors which has the most significant effect on occupant satisfaction (Kim & Dear, 2011). Hence, four basic components, namely thermal comfort, indoor air quality (IAQ), aural and visual comforts are identified for determining an acceptable IEQ (Frontczak and Wargocki., 2011 cited Lee *et al*, 2011). Compared to past work environments, the design of a modern work environment must anticipate high levels of spatial and technological change by providing responsive thermal and air quality delivery systems, as well as flexible technology infrastructures. However, the current standards and guidelines for indoor environments were predominantly developed based on experiments involving human subjects in environmental chamber conditions without consideration of these modern office variables (Loftness *et al*., 2009 cited Lee *et al*., 2009).

Furthermore, the design of high performance, green buildings promise to provide a better and healthier environment for occupants (Kamaruzzaman *et al*., 2010). Typical benefits of sustainable or green buildings include savings from operating costs and the increased bottom line through higher employee satisfaction and job performance due to the better quality of indoor environment (Kats *et al*., 2003 cited Lee *et al*., 2009). The demand from clients, the satisfaction from tenants, and the higher productivity from occupants due to GB are possible means to motivate the business stakeholders. A better understanding of the needs and expectations of the business stakeholders will bridge the gap between government and the market which make the GB more preferable to conventional buildings. Construction clients are demanding assurance of their buildings' long-term economic and environmental performance and costs. The problem for the best environmentally friendly buildings is that the environmental attributes are often invisible and only appreciated once the building is occupied and in use (Bartlett & Howard, 2000).

According to Edwards (1998), the benefits of bioclimatic or green buildings include lower energy and operational costs, market advantages for the building developer, higher indoor environmental quality and therefore living quality or higher productivity the inhabitants and lower long-term exposure to environmental or health endangering factors. Green buildings also have indirect benefits and advantages compared to conventional ones: they establish a psychologically and mentally more pleasant indoor environment, due to the utilization of natural lighting and ventilation (Karkanias *et al*., 2010). Accordingly, green building users are more forgiving of their green building, which work best with 'green' occupants. Nonetheless, it amplifies how occupant attitudes and expectations play an important role in the way green buildings are designed, built and received. Psychological dimensions of occupant adaptation, such as attitudes, expectation and control are important to consider in green building design. However, future studies across a broader sample of buildings are needed to understand how occupants' pro environmental attitudes influence their tolerance of green buildings. Given the urgency to mitigate global warming, it has become apparent that people's attitudes, and the behaviours they entail, can be shifted. Whilst buildings take years to build or months to retrofit, the path to altering people's expectations of the built environment presents another, potentially more accessible strategy to moving buildings towards more green from non-green buildings (Deuble & Dear 2012).

3. SUMMARY

The increasing consensus on climate change has resulted in escalating demands on the public to make better environmental choices in building construction. It is widely recognized that the current environmental crisis is a human problem and solutions depend on major changes in human attitudes, expectations and actions. Hence, it emerges the importance of facilitating high quality indoor environment within buildings. Consequently, many tools and concepts have been developed to determine criteria for healthy and comfortable buildings with high quality indoor environment. Green building concept has emerged as a new building philosophy to provide better and healthier indoor environment for building occupants. Hence, the modern practice extended and complemented the conventional building construction process to achieve sustainable or high performance building. There is also more potential to change the existing buildings to be more 'green', as the quality of built environment is a major expectation of building occupants. The occupants have been favourably disposed to green buildings from their conventional environments. It is due to the certainty of reaching their expectations specially to obtain comfortable working environment. It implies that the occupants' expectations are significance for the acceptance of any green building specially in moving from their typical working environments. The reason is that the poor fit between the built environment and the needs and expectations of the occupants may lead to dissatisfaction, health issues and productivity losses. Henceforth, occupants' attitudes and expectations play an important role in the way green buildings are designed, built and received and its acceptance.

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IMPROVING INDOOR AIR QUALITY FROM EFFECTIVE VENTILATION SYSTEMS IN OFFICE BUILDINGS IN SRI LANKA

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ABSTRACT

Indoor air quality (IAQ) becomes a major consideration in indoor environments as it directly affects occupants' health and comfort. Sick building syndrome (SBS) and adverse perception on IAQ had become significant issues of poor IAQ in Sri Lankan context. These IAQ problems arise due to poorly designed, maintained, or operated ventilation systems. Further, different types of ventilation systems such as natural ventilation and mechanical ventilation have different impacts in IAQ. Yet, it is important to identify IAQ issues in order to improve IAQ through effective ventilation systems. Therefore, this research was aiming to identify IAQ issues with the intention of improving IAQ from effective ventilation systems in office buildings in Sri Lanka. A quantitative research approach based on questionnaire survey and observation were used in order to achieve the objectives. A statistical analysis was carried out to obtain findings of the research. The study revealed that occupants in naturally ventilated buildings were healthier compared to occupants in MVAC buildings.

Keywords: *Indoor Air Quality; MVAC, Natural Ventilation; Sick Building Syndrome.*

1. BACKGROUND

Indoor Air Quality (IAQ) has become a significant environmental issue in office buildings (Mui and Chan, 2006). The number of related complaints has increased in recent years with increased building tightness, the growing use of synthetic materials, and energy conservation measures that reduce the amount of outside air supply (Pan *et al.*, 2006). Mui and Chan (2006) explained that, modern office equipment (photocopiers, laser printers and computers), cleaning products, and outdoor air pollution can also increase the level of indoor air contamination. Therefore, IAQ tends to become more polluted with the modern developments.

A study by European Federation of Asthma and Allergy Association (2001 cited Dijiken *et al*., 2006) stated that, building components, occupants, finishing, furnishings, building services and equipment contribute to the release of pollutants to indoor air. Poor IAQ in buildings leads to sick building syndrome (SBS) and cause adverse effect to occupants (Cheong *et al*., 2006). According to Charted Institute of Building Service Engineers (CIBSE) (2006) SBS symptoms may include fatigue, feeling heavy- headed, headache, sleepy, difficult to breath, dry nose, blocked nose, hoarse, dry throat, dry lips and dry skin. Even though these symptoms may not be obviously related to a particular cause, they become less severe or disappear when they leave a particular environment (CIBSE, 2006). According to CIBSE (2006), if a significant proportion of occupants experience these symptoms then, occupants are suffering from SBS. According to Wargocki *et al.* (2000), ventilation flow rate can be increased to improve indoor air quality and to decrease the SBS symptoms. Increased risk of SBS and elevated prevalence of general SBS symptoms were associated with low outdoor-air flow rates, presence contamination in office rooms, and unacceptable temperature and humidity levels (Sundell, 1994). According to Cheong *et al*., (2006) symptoms of SBS can be minimized using proper ventilation.

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Johnson (2000) defined that ventilation as the process of exchanging air between the outdoors and the conditioned space for the purpose of diluting the gaseous contaminants in the air and improving or maintaining air quality, composition and freshness. Ventilation systems are widely used to improve IAQ, besides eliminating contamination sources and purifying the air (Fanger, 2006; Yu *et al*., 2009). Furthermore, a study by Modera and Andrew (1995 cited Dols and Persy 1995) showed that effective ventilation systems should designed to provide sufficient level of outdoor air to the building, to remove contaminants generated within the space, to provide comfortable environment to the building occupants. Therefore, the purpose of ventilation system is to provide acceptable microclimate in the space being ventilated (Awbi, 2003). Air quality benefits provided by ventilation systems include improving relative humidity and reducing volatile organic compounds (VOCs) as well as removing carbon dioxide from the air and producing oxygen (Smith and Pitt, 2009). Effectiveness of building ventilation system is a primary determinant of IAQ in buildings as it impacts indoor contaminant concentrations and occupants comfort (Persily *et al.*, 2006).

The designers and operators of ventilation systems should be familiar with the comfort requirements and the quality of air necessary to achieve acceptable indoor climate (Awbi, 2003). Designers should minimize uncontrolled air leakage into a building, minimize demand by over-design, giving preference to natural ventilation, choose efficient primary plant, consider energy recovery, distribute air effectively, and use effective controls (Charted Institute of Building Service Engineers (CIBSE), 2004). A study by Modera and Andrew (1995 cited Dols and Persy, 1995) showed that, the design of building ventilation systems should be based on ventilation standards that specify minimum levels of ventilation for occupant health and comfort. Ventilation for acceptable indoor air quality standard 62.1-2007 by American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) is a voluntary standard for minimum ventilation rates (ASHRAE, 2007). This is the most widely used ventilation standard in Sri Lankan context. Designers and operators need to have a better understanding about ventilation system standards in order to have an effective ventilation system.

Ventilation requirement can be provided with different types of ventilation systems. It is generally accomplished by natural ventilation and mechanical ventilation (Merritt and Ricketts, 2000). Stavrakakis *et al.* (2008) stated that, the proper design of natural ventilation must be based on detailed understanding of airflow within enclosed spaces, governed by pressure differences due to wind and buoyancy forces. Natural ventilation includes many benefits over mechanical ventilation such as low cost, flexibility, maintainability and fewer symptoms of SBS (Hummelgaard *et al*., 2007; Xuea *et al*., 2004). Mechanical ventilation and air conditioning (MVAC) system is a type of mechanical ventilation system most commonly used in multi-storey buildings to enable effective ventilation with cooling and dehumidification (Franssona *et al*., 2007). Therefore, this research was conducted to identify IAQ issues with the intention of improving IAQ through effective ventilation systems in office buildings in Sri Lanka.

2. RESEARCH METHODOLOGY

Surveys are normally used where the views or opinions of many need to be evaluated in order to achieve a conclusion. Therefore, survey research has been selected as the most suitable research approach. Structured questionnaire was selected as the best data collection techniques. Statistical analysis of percentage, mean average and Chi-Square test was used for data analysis.

Questionnaire survey was focused on occupants overall assessment on indoor air quality, their perception of personal control and frequency of occurring symptoms of naturally ventilated office buildings as well as office buildings with MVAC systems. Data was collected from fifty occupants from naturally ventilated buildings and fifty occupants from MVAC buildings. Employees who perform sedentary work were given the questionnaire in each building and personal survey method was conducted. Sedentary office workers usually spend total working hours (8 hours) at their work desk. Therefore, those office workers become more sensitive to their working environment and variations in working environment directly affect them.

CHI- SQUARE ANALYSIS

The Chi-Square ($\chi 2$) test, also called Pearson's Chi-square test is used to discover if there is a relationship between two categorical variables. The Chi-Square test is performed to test whether two variables can be considered statistically independent. In this research Chi-Squared test was used to determine whether there is a relationship between conditions of the working environment (naturally ventilation/ MVAC) to occurrence of symptoms of SBS for occupants.

Hypothesis

Ho: Prevalence of symptoms are not associated with condition of the office environment (Natural ventilation /MVAC), and

H_1: Prevalence of symptoms is associated with condition of the office environment (Natural ventilation /MVAC)

Decision Rule

Reject H_o if $p < 0.05$

3. RESEARCH FINDINGS

3.1. PREVALENCE OF SYMPTOMS OF SBS

Survey was carried out in five naturally ventilated buildings and five mechanically ventilated and air conditioned buildings. The gender of the respondents was 54% female and 46% male for naturally ventilated offices and 48% female and 52% male for mechanical ventilation and air conditioned (MVAC) offices. Structure questionnaire survey was focused on ten symptoms of SBS. A five point Likert scale was used to collect occupant's responses, scale was as follows.

1 – No, never
2 - Yes, rare
3 - Yes, sometimes
4 - Yes often (every week)
5 - Yes, daily

Analysis was carried out to identify frequency of occurring symptoms for building occupants under three types of time periods; "at least rare", "at least sometimes" and at "least often". "At least rare" represents four optional answers in the Likert scale {(2-Yes, rare), (3-Yes, sometimes), (4 – Yes, often (every week)), and (5 - Yes, daily)}. This gives the number of respondents who get each symptom at least rarely. This can be illustrated as in Figure 1.

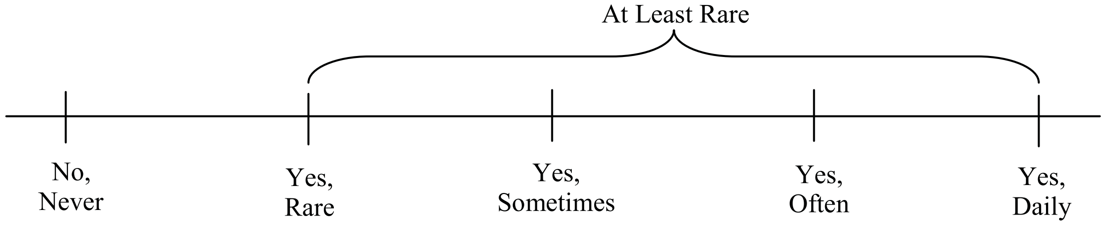


Figure 1: Time Scale of "At Least Rare"

"At least sometimes" represents three optional answers in the Likert scale {(3-Yes, sometimes), (4 – Yes, often (every week)) and (5 - Yes, daily)}. This gives the number of respondents who get each symptom at least sometimes. This time scale can be illustrated in Figure 2.

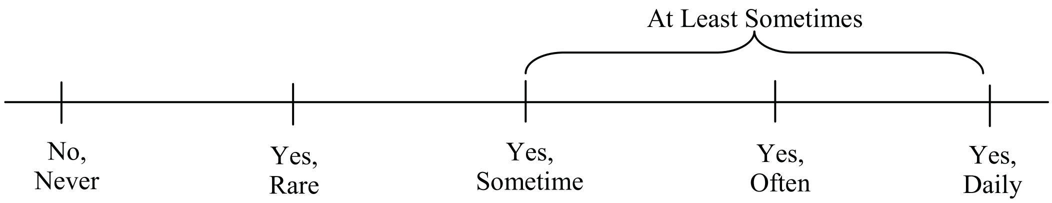


Figure 2: Time Scale of "At Least Sometimes"

“At least often (every week)” represents two optional answers in the Likert scale {(4 - Yes, often (every week)) and (5 - Yes, daily)}. This gives the number of respondents who get each symptom at least weekly.

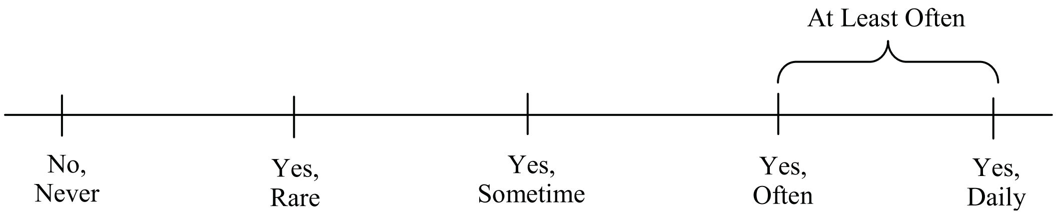


Figure 3: Time Scale of "At Least Often"

When addressing IAQ issues firstly symptoms which occur at least often should be treated. Finally, mitigation strategies can be taken to avoid symptoms occur at least rarely.

FREQUENCY OF OCCURRING SYMPTOMS – “AT LEAST RARE”

Table 1 shows prevalence of SBS symptoms based on occupants who reported they had symptom “At least rare”. Furthermore, the prevalence of symptoms of SBS was also compared between occupants in two building type in Table 1. The arrows indicate whether the symptoms prevalence in naturally ventilated offices was higher (↑) or lower (↓) than in buildings with MVAC systems.

Table 1: Prevalence of Symptoms among Occupants Experienced “At Least Rare”

“At least rare” (Summation four optional answers for Yes; “yes, rare”, “yes, sometimes”, “yes often”, and “yes, daily”.)				
No	**Symptom**	**Natural ventilation offices (n= 50)**	**MVAC offices (n=50)**	**Natural ventilation Vs MVAC offices**
1	Fatigue	41	30	↑
2	Feeling heavy- headed	35	37	↓
3	Headache	33	41	↓
4	Sleepy	29	40	↓
5	Difficult to breath	28	45	↓
6	Dry nose	27	42	↓
7	Blocked nose	25	38	↓
8	Hoarse, dry throat	22	41	↓
9	Dry lips	21	48	↓
10	Dry skin	22	46	↓

The prevalence of overall symptoms occurring "At least rare" was higher in mechanically ventilated offices. Prevalence of all symptoms was higher in buildings with MVAC except fatigue.

CHI- SQUARE ANALYSIS – "AT LEAST RARE"

Hypothesis

Ho: Prevalence of symptoms are not associated with condition of the office environment (Natural ventilation /MVAC), and

H_1: Prevalence of symptoms are associated with condition of the office environment (Natural ventilation /MVAC)

Decision Rule

Reject H_o if $p < 0.05$

Table 2 shows the P value of Chi- Square analysis between naturally ventilated buildings and MVAC buildings.

Table 2: Chi Square Analysis - "At Least Rare"

Chi- Square Analysis - "At least rare" (Represent four optional answers for Yes; "yes, rare", "yes, sometimes", "yes often", and "yes, daily".)		
No	**Symptom**	**P - value**
1	Fatigue	0.015
2	Feeling heavy- headed	0.656
3	Headache	0.068
4	Sleepy	0.017
5	Difficult to breath	0.000
6	Dry nose	0.001
7	Blocked nose	0.021
8	Hoarse, dry throat	0.000
9	Dry lips	0.000
10	Dry skin	0.000

Chi- Square Analysis shows that prevalence of symptoms occurring "At least rare" was significantly higher in buildings which has MVAC systems for "sleepy" (P = 0.017, χ^2- test), difficult to breathe (P = 0.000, χ^2- test), dry nose (P = 0.001, χ^2- test), blocked nose (P = 0.021, χ^2- test), dry throat (P = 0.000, χ^2- test), dry lips (P = 0.000, χ^2- test) and dry skin (P = 0.000, χ^2- test). Fatigue (P = 0.015, χ^2- test) was significantly higher in naturally ventilated buildings. No significant differences were observed when comparing the prevalence of the feeling heavy- headed (P = 0.656, χ^2- test) and headache (P = 0.068, χ^2- test).

According to the analysis P values of fatigue, sleepy, difficult to breathe, dry nose, blocked nose, dry throat, dry lips and dry skin were lower than 0.05 which is the pre specified significance level. Therefore, null-hypothesis can be rejected. Alternative hypothesis is accepted which is the "prevalence of symptoms is associated with condition of the office environment".

FREQUENCY OF OCCURRING SYMPTOMS – "AT LEAST SOMETIMES"

Table 3 shows the prevalence of symptoms of occupants who reported that they felt a symptom "At least sometimes".

Table 3: Prevalence of Symptoms among Occupants Experienced "At Least Sometimes"

"At Least Sometimes" (Represent three optional answers for yes; "yes, sometimes", "yes often", and "yes, daily")				
No	**Symptom**	**Natural ventilation offices (n= 50)**	**MVAC offices (n=50)**	**Natural ventilation Vs MVAC offices**
1	Fatigue	14	12	↑
2	Feeling heavy- headed	7	15	↓
3	Headache	5	20	↓
4	Sleepy	2	12	↓
5	Difficult to breath	1	10	↓
6	Dry nose	1	11	↓
7	Blocked nose	3	13	↓
8	Hoarse, dry throat	3	13	↓
9	Dry lips	5	35	↓
10	Dry skin	8	28	↓

The prevalence of overall symptoms occurring "at least sometimes" was also higher in mechanically ventilated offices except fatigue.

CHI- SQUARE ANALYSIS – "AT LEAST SOMETIMES"

Hypothesis

Ho: Prevalence of symptoms is not associated with condition of the office environment (Natural ventilation /MVAC), and

H_1: Prevalence of symptoms is associated with condition of the office environment (Natural ventilation /MVAC)

Decision Rule

Reject H_o if $p < 0.05$

Table 4 shows the P value of Chi- Square analysis between naturally ventilated buildings and MVAC buildings.

Table 4: Chi- Square Analysis - At Least Sometimes

Chi- Square Analysis – "At least sometimes" (Represent three optional answers for yes; "yes, sometimes", "yes often", and "yes, daily".)		
No	**Symptom**	**P - value**
1	Fatigue	0.648
2	Feeling heavy- headed	0.530
3	Headache	0.001
4	Sleepy	0.004
5	Difficult to breath	0.004
6	Dry nose	0.002
7	Blocked nose	0.012
8	Hoarse, dry throat	0.006
9	Dry lips	0.000
10	Dry skin	0.000

Chi- Square Analysis shows that prevalence of symptoms occurring “At least sometimes” was significantly higher in buildings which has MVAC systems for headache (P = 0.001, χ^2- test), sleepy (P = 0.004, χ^2- test), difficult to breathe (P = 0.004, χ^2- test), dry nose (P = 0.002, χ^2- test), blocked nose (P = 0.012, χ^2- test), dry throat (P = 0.006, χ^2- test), dry lips (P = 0.000, χ^2- test) and dry skin (P = 0.000, χ^2- test).

Fatigue and feeling heavy headed have P values higher than 0.05. This tells that there is no statistically significant association between condition of office environment and prevalence of these two symptoms.

FREQUENCY OF OCCURRING SYMPTOMS – “AT LEAST OFTEN”

Table 5 shows the prevalence of occupants who reported that they felt a symptom “at least often”.

Table 5: Prevalence of Symptoms among Occupants Experienced “at least often (every week)”

At least Often (Every Week) (Represent two optional answers for Yes; “yes, often” and “yes, daily”.)				
No	**Symptom**	**Natural ventilation offices (n= 50)**	**MVAC offices (n=50)**	**Natural ventilation Vs MVAC offices**
1	Fatigue	6	5	↑
2	Feeling heavy- headed	3	6	↓
3	Headache	3	11	↓
4	Sleepy	1	5	↓
5	Difficult to breath	1	1	-
6	Dry nose	0	4	↓
7	Blocked nose	2	4	↓
8	Hoarse, dry throat	2	3	↓
9	Dry lips	5	24	↓
10	Dry skin	7	20	↓

The prevalence of eight symptoms among all ten symptoms, were higher in mechanically ventilated offices.

CHI- SQUARE ANALYSIS – “AT LEAST OFTEN”

Hypothesis

Ho: Prevalence of symptoms is not associated with condition of the office environment (Natural ventilation /MVAC), and

H1: Prevalence of symptoms is associated with condition of the office environment (Natural ventilation /MVAC)

Decision Rule

Reject Ho if $p < 0.05$

Table 6 shows the P value of Chi- Square analysis between naturally ventilated buildings and MVAC buildings.

Table 6: Chi- Square Analysis - At Least Often

Chi- Square Analysis – "At least often" (Represent three optional answers for yes; "yes, sometimes", "yes often", and "yes, daily")		
No	**Symptom**	**P - value**
1	Fatigue	0.749
2	Feeling heavy- headed	0.295
3	Headache	0.021
4	Sleepy	0.092
5	Difficult to breath	1.000
6	Dry nose	0.041
7	Blocked nose	0.400
8	Hoarse, dry throat	0.646
9	Dry lips	0.000
10	Dry skin	0.003

Chi- Square Analysis shows that prevalence of symptoms occurring "at least often" was significantly higher in buildings which has MVAC systems for headache (P = 0.021, $\chi 2$- test), dry nose (P = 0.041, $\chi 2$- test), dry lips (P = 0.000, $\chi 2$- test) and dry skin (P = 0.003, $\chi 2$- test).

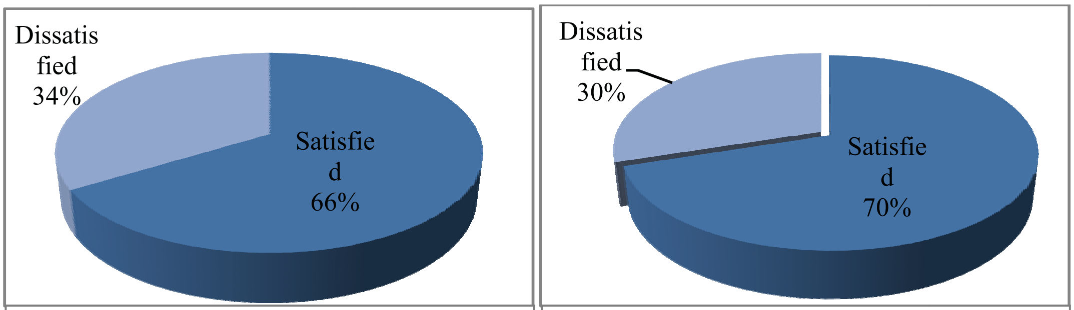
Other symptoms have P values higher than 0.05. This tells that there is no statistically significant association between condition of office environment and prevalence of these symptoms "at least often".

OUTCOME OF PREVALENCE OF SICK BUILDING SYNDROME (SBS) SYMPTOMS

Occupants in Buildings experienced acute health and comfort effects that appear to be linked to time spent in a building. Findings of the questionnaire survey showed that prevalence of symptoms were high in MVAC buildings compared to naturally ventilated buildings. Out of ten symptoms only fatigue was high in naturally ventilated buildings. Dry nose, dry skin, dry lips and headache were the symptoms that most of occupants experienced often. Apart from this sleepy, difficult to breathe, dry throat and blocked nose were the symptoms that occupants experienced sometimes. These symptoms occur due to poor indoor air quality, therefore it can be stated that office buildings in Sri Lanka have many IAQ issues.

3.2. OCCUPANTS' LEVEL OF CONTROL

Occupants in buildings with MVAC systems felt they can have a significantly higher ability to adjust the temperature at their workplaces. Seventy percent of the occupants in MVAC office buildings felt they have an ability to control the indoor environment at their workplaces. Only sixty six percent of the occupants in naturally ventilated buildings felt they have an ability to control the indoor environment at their workplaces.



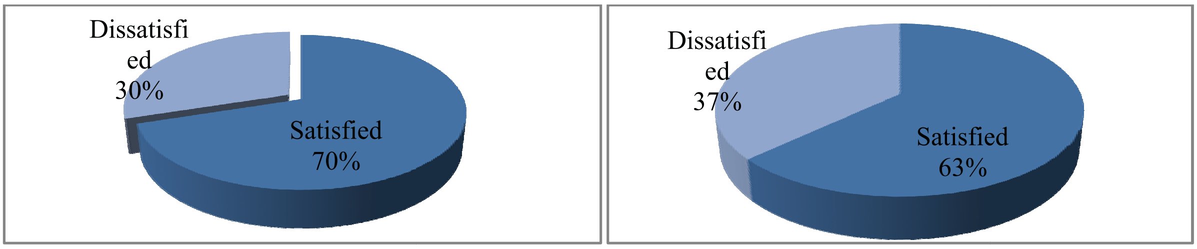
Satisfaction on ability to control IAQ in naturally ventilated offices	Satisfaction on ability to control IAQ in offices with MVAC

Figure 4: Satisfaction on Ability to Control IAQ

Occupants in MVAC environments can adjust thermostat and flow of air to meet their comfortable requirements. Occupants in naturally ventilated buildings can open or close doors and windows to control flow of air to some extent. However, they can hardly control the temperature. Therefore, occupants in MVAC office buildings were more satisfied on their ability to control IAQ when compared to occupants in naturally ventilated offices.

3.3. OCCUPANTS' SATISFACTION ON IAQ

Seventy percent of the occupants in the naturally ventilated buildings were replied that they were satisfied with the IAQ, whereas only sixty three percent were satisfied in the mechanically ventilated offices. Even though the difference is not significant, occupants in naturally ventilated buildings were more satisfied on IAQ when compared to buildings with MVAC. Usually occupants in controlled environments such as air conditioned environments have higher expectations on IAQ. Therefore, occupants in MVAC environments have higher expectations compared to occupants in naturally ventilated environments. When their expectations are failed to meet they get dissatisfied very easily. Figure 5 illustrate these results.



Occupant satisfaction on IAQ in naturally ventilated offices	Occupant satisfaction on IAQ in offices with MVAC

Figure 5: Occupant Satisfaction on IAQ

4. CONCLUSIONS

It was clear that occupants in office buildings in Sri Lanka suffer due to poorly maintained IAQ. According to research findings occupants in naturally ventilated buildings healthy than occupants in MVAC buildings as they experience less symptoms of SBS. Further, findings showed that occupants in naturally ventilated buildings were more satisfied on IAQ compared to MVAC buildings. Occupants in MVAC buildings have adverse perceptions on too low room temperature, stuffy (bad) air and dry air. Occupants in naturally ventilated buildings feel adverse perception about high room temperature, varying room temperature and draught. As Sri Lanka has a tropical climate, natural ventilation could not be able to reduce air temperature significantly. Therefore, it is important to address IAQ issues with the intention of improving IAQ by effective ventilation systems.

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INFLUENCE OF CHANGE MANAGEMENT FOR EFFECTIVE OUTSOURCING OF FACILITIES MANAGEMENT SERVICES

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ABSTRACT

The procurement by partial or full outsourcing of Facilities Management services is one of the options available for operation and maintenance of buildings. Since the recent past, this has been observed as a popular trend in this sector. Outsourcing can bring about many changes and conflicts into the organisation. This is due to many reasons such as services being performed in different ways, some services changing in quality and rhythm, the employees being asked to do things differently and the organisational culture also having to adopt the changes. Organisations need to adopt an intelligent approach to manage such changes if they are to maintain the continuity of the operations. As such, the aim of this study is to identify the influence of change management towards the effective outsourcing of Facilities Management services. Multiple case study method was adopted as the research methodology for this purpose. Data were analysed against the three predetermined categories which were; reasons for the outsourcing, the impact of change during outsourcing practices, and incorporating the change management with the outsourcing practices, in order to reach a compromise. Findings of the study reveal that the efficiency of outsourcing the Facilities Management services can be improved and the organisations can reap the maximum benefit out of such outsourcing if the change management is handled in an effective manner.

Keywords: *Change Management; Facilities Management; Outsourcing.*

1. INTRODUCTION

Outsourcing has been advanced to the extent of being one of the most popular and widely adopted business strategies in this era of globalisation (Cigolini *et al.*, 2011; Willcocks, 2010). Outsourcing is the act of transferring some of the organisation's recurring internal activities and the right of decision making to outside providers as set forth by a contract (Greaver, 1999). Hence, it involves the transfer of responsibilities (Krell, 2006). In a competitive business environment, companies focus on core activities and outsource non-core functions to others (Kim and Won, 2007; Quinn and Hilmer, 1994). In the field of Facilities Management (FM), it involves the "contracting out" of FM services to an external provider (Atkin and Brooks, 2009; Barret, 2000). Up to now outsourcing has contributed immensely to the growth of FM as an industry and in the foreseeable future it is also likely to be the driving force of the industry (Best *et al.,* 2003). According to the International Association of Outsourcing Professionals (2011, cited in Ikediashi *et al*, 2012), the global outsourcing industry is presently worth over $1 trillion annually with India capturing a lion share of the market closely followed by China.

The FM industry in Sri Lanka too uses outsourcing as one of their procurement strategies (Nadeeshani, 2006). Nadeeshani (2006) found that during the decision making process of procurement strategy in the FM industry in Sri Lanka, change management issues such as employee reactions, ethical and cultural impacts, willingness to manage possible discords that could arise out of contract in the future, were neglected or received the least of attention.

Andersen and Ankerstjerne (2011) stated outsourcing as a service creates many changes and possible disruptions to an organisation. Also, Atkin and Brooks (2009) theorise that, change is normal, but for the people affected by such change the consequences can be substantial. Therefore, organisations need

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to adopt an intelligent approach to planning, coordinating and controlling the process of change that ensures continuity of operations (Atkin and Brooks, 2009; Gildner, 2006).The problems that may arise from unmanaged change in outsourcing are; cultural conflicts, loss of interest by employee, breakdown of communications regarding goals and commitments, non-corporation between the organisation and service provider (Andersen and Ankerstjerne, 2011). Moreover, the difficulties on the part of the employees to make even small changes to their work habits tend to be underestimated by the managers. Consequently, sometimes this may result in reluctance and resistance by employees as a result of which the managers often lose patience, and that could possibly lead to further antagonisms (Andersen and Ankerstjerne, 2011). Accordingly, the aim of this paper is to review the importance of incorporating change management during outsourcing of Facilities Management services and to identify the influence of change management towards the effective outsourcing of Facilities Management services. This is to be dealt here in sequence of specific topics consisting Nature of Outsourcing, Impact of Change in Outsourcing Practices, Incorporating Change Management during Facilities Management Outsourcing Practices, Research Method, Data Analysis, and Conclusion.

2. NATURE OF OUTSOURCING

Outsourcing is an act of moving some of a firm's internal activities and decision making responsibilities to outside providers as defined by Chase *et al.* (2004). Furthermore it is a condition where an organisation contracts with another for the provision of a service that could well be provided by a person, unit or department within the same organisation that requested the service (Best et al., 2003; Barret, 1995; Barret, 2000).This defines that outsourcing is the process of assigning or transferring the non-critical business activities from an internal source to an external party. In order to achieve a long term competitive advantage a firm should concentrate more on its core activities. Therefore many organisations are of the view that outsourcing firms can carry out those non-core activities more effectively at a lower cost (Smith *et al.,* 2000).

The main three subcategories in FM outsourcing are, the Managing Agent, who is appointed as a specialist to act as the client's representative. This person (or organisation) is responsible for arranging the appointment of the service providers. Secondly the Managing Contractor, which as an organisation that has the responsibility to manage all service providers under one umbrella as though being part of one large contracting organisation. The contractor being paid a fee for providing such services, usually as a percentage of the value of the expenditure managed, and thirdly Total Facilities Management, where a single organisation is delegated the responsibility for providing services and for generally managing the facilities (Atkin and Brooks, 2009).

Organisations select outsourcing as a Facilities Management procurement option due to several reasons. The most common of the reasons for outsourcing are shown in Figure 1. Once the organisation decides to outsource, it should first develop a list of suppliers/vendors for consideration, and then appoint an Implementation and Governance team for the outsourcing process so that they could carry out an effective selection and monitoring of the process (Brown and Wilson, 2005). According to Nadeeshani (2006) in Sri Lanka, the FM industry gives priority for quality, flexibility, innovation and price during the process of vendor selection.

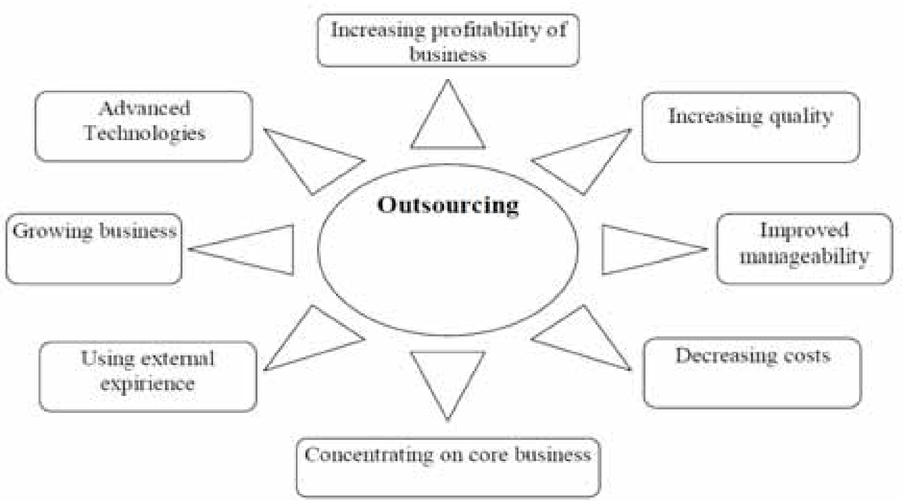


Figure 1: Reasons for Outsourcing (Adopted from: Borisova, 2011)

According to Brown and Wilson (2005) the outsourcing process is made up of six phases. At first is the Strategy Phase which defines the objectives and scope of the outsourcing process and also determines the feasibility of the process. Moreover, it includes the planning for the total effort in terms of time, budget, and the necessary resources required for the initiation of the process. Secondly the Scope phase which establishes the baselines and specifies the service levels required from the vendors. Furthermore in order to provide the proper interfaces between the two parties it clarifies the relationships between the functions to be outsourced and those functions that are to remain in house. Thirdly the Negotiation phase where negotiations proceed with the chosen vendor until a contract is drawn up and, signed by both parties. Fourthly the Implementation phase marks the transition of services provided from in house to outsource. Fifthly the Management phase where the relationship between organisation and vendor is to be managed. It includes the negotiation and implementation of any changes in the outsourcing relationship seen as necessary to ensure a successful outcome. Sixthly at the end of the contracting period will be the Completion or termination phase where organisation will make the decision either to negotiate another contract with the same vendor or to terminate that relationship and align with a new vendor in which case the cycle commences all over again. Sometimes the organisation may decide to switch back into in-house system in this phase.

3. IMPACT OF CHANGE IN OUTSOURCING PRACTICES

Change is a movement from the present state of the organisation to a desired future state (Ramanathan, 2008). Different approaches can be adopted to manage change. Figure 2 presents a generic process model based on Lewin (1958) and Kotter (1996) that enables to understand the change process. It highlights the significance of following four components; contextual conditions prompting the change (external and internal factors), diagnosing the need for change and developing plans for implementation, followed by implementing such plan and then finally institutionalizing the change (Ramanathan, 2008). This generic process model has been combined into the outsourcing change management process and is discussed in topic 4.

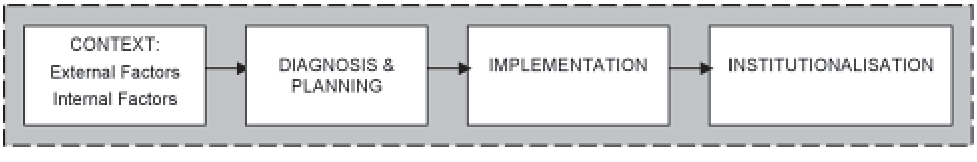


Figure 2: Generic Process Model of Change (Adopted from: Ramanathan, 2008)

Corporate culture and practices are unique to each organisation. This could be so to even those involved in the same industry. Outsourcing and admitting a vendor with an entirely different culture into the organisation can give rise to cultural clashes particularly if such organisations are not in a state of preparedness to accept the outsider. Organisations should not underestimate these differences (Brown and Wilson, 2005). Each organisation has its own established practices, principles and values which are well entrenched and hence initially may resist changes to the system that outsourcing forces upon them (Andersen and Ankerstjerne, 2011). There may be interruptions resulting from this which may affect the quality of the services and the entire productivity of the organisation. However, making change happen successfully is one of the most challenging tasks faced by the leadership and corporate management of the organisation. Therefore organisations should adopt methodical approach in order to reduce the consequences of unmanaged change. The common issues which may arise from unmanaged change are discussed below.

3.1. NO SUPPORT FROM CLIENT ORGANISATION STAFF

Due to the different procedures adopted by the outsourcing provider in handling the services, the in-house staff may be reluctant to co-operate and participate in the activities carried out by the vendors (Ikediashi *et al*, 2012). This can result in active or passive resistance against the entire outsourcing model. Due to lack of co-operation the vendor also will not be able to execute the functions in the best way that he seems fit. Later it may lead to dissatisfaction of top management and that would eventually affect industrial peace.

3.2. POOR MUTUAL UNDERSTANDING

After signing the initial contract, both the client and service provider have multiple team members who would be responsible to manage the initial activities of implementation and ongoing operations. Following the changes in the organisation the client's staffs are already emotionally charged and are beginning to just learn the details of the agreement. Hence there is a tendency for them to dictate terms to the vendor regarding what he should (and should not) perform (McCray, 2008). This state of friction may result in operational disruptions.

3.3. POOR ACCOUNTABILITY

In instances where both the in-house and the outsource parties are expected to work in co-operation and share responsibilities to complete a service, none of them would be willing to take accountability for any occurrence of downtime or productivity loss (Ikediashi *et al*, 2012).

3.4. CULTURAL CLASHES BETWEEN CLIENT AND SERVICE PROVIDER

In terms of corporate culture, the client and the service provider may have different norms in terms of speed, style, decision making and organisational structure. The fact that outsourcing represents a commercial relationship between two separate entities that can hold on to extreme and inflexible positions also serves as another potential flash point (McCray, 2008).

4. INCORPORATING CHANGE MANAGEMENT DURING FACILITIES MANAGEMENT OUTSOURCING PRACTICES

Effective management of change during outsourcing process ensures maximum value for the organisation. For any manager involved in an outsourcing initiative the most daunting of challenges would be that of coping with the changes caused by outsourcing, both by the process and personnel (Brown and Wilson, 2005). Often these change related aspects are not addressed by traditional strategic planning (Worley *et al*., 1996). Organisations often ignore the fact that successful outsourcing is heavily dependent upon the attitudes of their workforce. The perspectives and responses of employees at all levels and positions have a significant impact on the successful implementation of strategic change processes (McIvor, 2005).

So as to coordinate and negotiate the changes across the entire outsourcing process and for all groups and individuals involved, communication becomes the key factor. Therefore the organisation should involve the staff during the early stages of the plan for outsourcing. This will help to build their trust, which will make them more willing to accept the changes and lend their support. Moreover the employees should be educated about the fact that they will need to change along, in order that more attention can be paid to the core business and its success so that ultimately their future will be more secure in the competitive environment (Brown and Wilson, 2005). Since the Facilities Management involves machineries and equipment, the vendor is in a position to introduce new technologies. A change in the work process or work activities may be necessary if new technology or new maintenance techniques are to be introduced by the outsourced party (Griffin, 2008). In such a situation proper training and awareness should be given to the in-house employees. Likewise in each phase of outsourcing the potential changes should be identified and change management initiatives should be incorporated accordingly.

4.1. CHANGE MANAGEMENT PROCESS TO BE INCORPORATED WITH OUTSOURCING PROCESS

The generic process model of change (Ramanathan, 2008) can be further modified to fit with outsourcing practices.

Step 1- Context: The influence of internal and external business environment creates a need by the organisation to go in for outsourcing. External environment factors namely commercial, social, and particularly economic factors such as cost would force an organisation to go for outsourcing (Usher, 2003). Internal business environment includes corporate plan, resource constrains, business objectives, and management styles also have an impact on outsourcing decisions. These internal and external factors normally decide the organisational values, norms and culture. The manager should take these factors into consideration when deciding the extent to which he has to manage the change (Ramanathan, 2008). At the same time sub cultures and sub culture gaps can arise in the organisation that could lead to serious problems such as employees leaving the organisation, resistance towards implementation of outsourcing, and so on (Finnegan and Willcocks, 2006).

Step 2- Diagnosis and Planning: In order to plan for change management, complete data regarding group and individuals should be collected, interpreted and analysed (Hayes, 2002). This will be helpful for the managers to find out about the current status of their organisation. Further Hayes (2002) stated this diagnosis can be done through SWOT (Strength, Weaknesses, Opportunities and Threats) analysis or PEST (Political, Environmental, Social and Technological) analysis. Following this diagnosis, the plan for the change management should be done based on the data collected during the diagnosis phase. In this phase a set of targets and objectives will be developed for implementation. This plan should be effectively communicated to all the stakeholders by a management team with specific roles and responsibilities assigned to its members (Ramanathan, 2008

Step 3- Implementation: The plan developed in the previous step will be executed in this step. According to Waldersee and Griffiths (cited Ramanathan, 2008) two major approaches can be adopted to implement the change management programme. One is the top down method and the other is the bottom up method. While the top down approach tends to be procedural, focusing on resource allocation and follow formal authority lines, the bottom up approach favours participative, and consultative techniques which targets the values, attitude and skills of the members in the organisation. Especially during outsourcing projects the ego issues arising from employees are likely to cause more resistance to change (McCray, 2008). Therefore implementation should be provided with a proper feedback system

Step 4- Institutionalisation: This step anchors changes in the corporate culture and makes the employees accustomed to the change. According to Kotter (1996) change can be institutionalised in two ways. Firstly by demonstrating the success caused by the changed behaviour. Secondly by the leadership adopting the new behaviour and norms and introducing it in the organisation. This is the step which is important to sustain the change which leads to effective outsourcing.

5. RESEARCH METHOD

Case study was selected as the most suitable research method for this study. The reasons being, the study needed to focus on in-depth decisions and behavioural attitudes of individuals and groups within and between organisations (Woodside, 2010).As such, the most appropriate sources of primary data were considered to be the expert opinions. 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.

This study selected multiple cases, as it provides multiple sources of evidence and potential replication of findings. Table 1 furnishes the list of interviewees. Each interview transcript was analysed against the three predetermined categories shown in Figure 3 around which the interview questions were structured so as to identity any commonalities or differences in opinion.

Table 1: List of Interviewees

Respondents	Type of organisation	Profile of the respondents
Respondent A	Private sector, Banking industry	Facilities Manager
Respondent B	Private sector, Manufacturing industry	Human Resources Manager
Respondent C	Private sector, Interior solutions industry	Facilities Manager

Name	Sources	References
Reasons for outsourcing	4	16
External expertise	3	3
Efficiency	2	2
Lower cost	2	2
Reduce the number of workers directly handled by the company	2	2
Better quality	1	1
Less burden	1	1
Faster replacement	1	1
Risk transfer	1	1
Single point responsibility	1	1
Improved productivity	1	1
Impact of change in outsourcing practices	3	4
Resistance of in house staff	1	1
Works may be performed in different ways	1	1
Poor understanding of scope of the work	1	1
Incorporating Change Management during Facilities Management Outsourcing Practices	4	7
Context analysis	1	1
Diagnosis and planning	3	3
Implementation	1	1
Institutionalisation	1	1

Figure 3: Nodes of Predetermined Categories for Analysis

6. DATA ANALYSIS

6.1. *REASONS FOR OUTSOURCING*

Table 2 shows the replies of the respondents regarding the reasons for selecting the outsourcing as their procurement option.

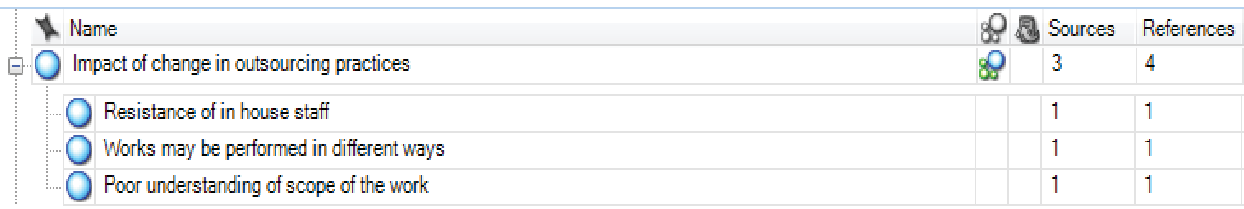
Figure 3: Nodes of Predetermined Categories for Analysis

Reasons	Respondent A	Respondent B	Respondent C
External expertise	✔	✔	✔
Efficiency	✔		✔
Lower cost		✔	✔
Reduce the number of workers directly handled by the company	✔	✔	
Better quality	✔		
Less burden			✔
Faster replacement		✔	
Risk transfer	✔		
Single point responsibility			✔
Improved productivity	✔		

Interview results illustrated that organisations undertake outsourcing for a variety of reasons depending upon their determination of the task. Most commonly organisations are going in for outsourcing in-order to acquire external expertise and concentrate more on their core business. According to Respondents B and C cost of outsourcing is lower. At the same time 'Respondent A' asserted "*outsourcing cost is slightly high compared to in-house but efficiency wise it is beneficial*". The probable reason for such statement from 'Respondent A' is presumed to be his non-considering the compulsory contributory costs such as EPF, ETF, gratuity and other allowances to be borne by the client company towards its in-house employees may not be applicable to the outsourced employees. Hence, the lump sum payment made to the outsourcing company may seem more. Therefore outsourcing is indeed beneficial cost wise. Risk transfer is another major reason for outsourcing. Though only 'Respondent A' has directly mentioned of it, the responses from other two respondents too indirectly demand risk transfer. Other reasons specified by the respondents were closely related to their respective fields of specialty.

6.2. *IMPACT OF CHANGE IN OUTSOURCING PRACTICES*

The outcomes from the interviews imply that, the change due to the presence of another organisation brings about an impact in the outsourcing efficiency. Figure 4 shows the issues as encountered by the respondents.



Name	Sources	References
Impact of change in outsourcing practices	3	4
Resistance of in house staff	1	1
Works may be performed in different ways	1	1
Poor understanding of scope of the work	1	1

Figure 4: Nodes of Impact of Change

Based on Respondent A's statement, the impact can be high, if an organisation has already been an in-house model for a long time then changes on suddenly to an outsource model. They may have to retire some of their in-house staff selectively and therefore they may face problems of employees resisting the change and with labour law restricting such retirements. The impact can be also high in case where the outsourcing organisation requests for replacement of particular machinery or a change of work process. Therefore this would have an impact on outsourcing efficiency. According to 'Respondent C' due to the improper understanding of the scope of their work initially by both in-house and outsourcing parties, one party may compete to keep ahead at the expense of other. This may result in reducing the efficiency of the outsourcing process. According to 'Respondent B', if the management is vigilant and proactive they can avoid such conflicts before it arises. Based on their responses it can be concluded there is an impact caused by change and that it should be mitigated.

6.3. *Incorporating Change Management During Facilities Management Outsourcing Practices*

All the respondents agreed that, in order to mitigate the conflicts due to change a proper change management practice should be incorporated during outsourcing practices. Their practices to manage change are given in Table 3.

Table 3: Ways to Incorporate Change Management

Respondent A	Respondent B	Respondent C
• Change management process should be carried out from the beginning of the process • Both positive and negative stakeholders should informed prior to change • Commitment and scope of both in-house and outsourcing parties should be communicated	• Continuous training should be given to the staff to adopt the way of working of the outsourcing party • Regular indirect monitoring of outsourcing party • Commitment and scope of both in-house and outsourcing parties should be communicated	• Commitment and scope of both in-house and outsourcing parties should be communicated

Findings from the literature reviewed for incorporating change management with the outsourcing practices agrees with the opinion expressed by the interviewees. According to the literature cited, the steps to incorporate change management are context analysis, diagnosis and planning, implementation and institutionalisation. Suggestions of the respondents can be fitted into these steps.

Step 1: Context analysis – This step is about analysing the internal and external environment in order to find the forces involved in the change. According to the respondents all positive, negative, internal and external stakeholders should be given prior information about the change, so that such stakeholders will exhibit minimum resistance to such changes.

Step 2: Diagnosis and planning – The outsourcing and the change management practices should be implemented simultaneously. For this purpose proper planning and diagnosis is necessary. Such a plan should communicate the scope and the commitment expected of both parties.

Step 3: Implementation – This step involves the execution of the change management plan. As an essential part of this plan in-house staffs should undergo continuous training. This will enhance their skills to a level compatible to that of the outsourced staffs.

Step 4: Institutionalisation – This step involves the organisation to get accustomed to the outsourcing. Regular monitoring is necessary to ensure the success of this step.

The responses were subjected to content analysis utilising NVivo 10 software and the results obtained are illustrated in Figure 5. According to this analysis the frequency of words used by the three respondents are highlighted in the order of importance.

Figure 5: Interviewees' Response

7. CONCLUSIONS

Outsourcing remains a powerful and an important strategic solution to the provision of a range of FM services. According to the findings, since organisations need to concentrate more on their core business activities, they favour outsourcing the non-critical business activities to a third party. Outsourcing creates many changes that may affect the efficiency of the in-house as well as outsourcing parties. In order to avoid the disagreements that may result from outsourcing, organisations need to adopt a measured approach towards this change. Steps for change management were identified from the literature and related with the findings to provide a feasible solution.

This paper explores the causal link between change management for effective outsourcing. A key suggestion for facilities managers is that they should recognise the importance of managing change during outsourcing practice and implement it in their profession. Basically putting things in proper process will determine the results and therefore managing the change from the beginning of the outsourcing process will increase the efficiency of it. As there will be a cost for this change we need to manage change so that it would be less painful, and help to sustain the outsourcing practices within the organisation in an efficient manner.

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IN-HOUSE VERSUS OUTSOURCING FACILITIES MANAGEMENT: A FRAMEWORK FOR VALUE-ADDED SELECTION IN SRI LANKAN COMMERCIAL BUILDINGS

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ABSTRACT

Facilities Management (FM) in the commercial building industry has been receiving increasing attention recently. FM is a multi-skilled profession which gives resources support for the core business because it concerns both optimizing building performance and ensuring the commercial success of the organization. However, in the Sri Lankan context, most organizations solely focus on the financial aspect while choosing between the outsourcing and in-house FM options, thus excluding other non-financial aspects such as the extent to which the FM route contributes to improving internal business processes and the overall strategic health of the organization. Hence, there is a need to arrive at specific framework for efficient decision making when choosing between the outsourcing and in-house FM approach for the purpose of addressing FM needs. However, the literature so far has failed to develop a framework when choosing the best FM approach for commercial buildings. The present research intends to fill this gap. This study presents the results of an investigation through a literature review into arriving at a holistic perspective on the key variables to be considered in choosing between outsourcing and in-house FM in order to provide value added services and to improve organizational performance. The paper therefore develops a decision support model for selection between outsourcing and in-house FM services through research.

Keywords: *Commercial Buildings; Facilities Management; In-house, Outsource.*

1. INTRODUCTION

1.1. BACKGROUND

Facilities management (FM) has been one of the fastest growing professional disciplines in the present (Lomas, 1999; Barrett and Baldry, 2003). International Facility Management Association (IFMA, 2012) defined FM as a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology. Further, FM provides an integrated approach for operating, maintaining, improving and adapting the buildings and infrastructure of an organization in order to create an environment that strongly supports the primary objectives of that organization (Barrett and Baldry, 2003).

In practice, FM covers a wide range of services comprising the real estate, financial management, change management, human resource management, health safety and contract management, in addition to building maintenance, domestic services and utility supplies (Atkin and Brooks, 2005). Further, Atkin and Brooks (2005) emphasized that these extensive facilities management functions may be successfully performed or provided either by in-house or out sourcing approach, on which the selection depends on the priority of the activities or services of an organization. Further, Barrett (1995) opines that some organizations favour a totally in-house option, while others literally contract out every service possible, yet others use a combination of both. However, most of the organization solely rely on cost factor in making a choice of in-house or outsource and mostly end up choosing outsource option. Further, there might be other factors which could prove in-house option to be effective in the long run.

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As a result, considering only the cost factor might be misleading and could result in a misalignment between FM services and corporate objectives of the organization (Cotts, 1999). To guard against this decision to choose between both approaches should be made having regarded to the path that lead to long-term best value for the organization

Hence, choosing an appropriate FM approach especially for commercial building becomes even more vital as in any country, among the variety of industries; commercial buildings provide a significant contribution to the economy (Fisher and Collins, 1999).As a result, some researches such as Nadeeshani (2006); Haseena (2010) and Meepage (2011) have conducted certain research on FM sourcing strategies as common basis to solve these issues. However, the extent of literature has failed to develop a framework or guideline to choose the best FM approach for commercial building in Sri Lanka. Moreover, in a developing country like Sri Lanka, the need of FM is becoming a prominent especially for commercial buildings. According to Nadeeshani (2006) emergence of large building properties in Sri Lanka has increased complexity of the supportive environment required for the core business of the organization. Thereby felt the need for a systematic approach for management of non-core activities of the Organization in the Sri Lanka. However, Currently, Professionals in Sri Lanka maintain their building without a proper guideline about choosing FM approach where they use their experience to take decisions which sometimes work and sometimes fail. Hence, there is always an uncertainty about these decisions where sometimes awful decision might bring massive loss to the organization.

Hence, it is proven that in Sri Lankan context, there is lack of efficient decision making frame work for choosing between outsourcing and in-house FM approach in meeting their FM needs. Hence, especially for the Sri Lankan commercial buildings, there is a requirement for any criteria or framework for efficient decision making to choose between outsourcing and in-house FM approach to fulfil the FM needs as at present, such criteria or frameworks are not available. Therefore, this research anticipates fulfilling the research gap that is to identify the key variables to consider in choosing between outsource and in-house FM in order to provide value added services and improving organizational performance.

1.2. AIM

The aim of this research is to develop a framework for value adding selection between outsourcing and in-house FM routes for the commercial buildings of Sri Lanka.

2. METHODOLOGY

A comprehensive literature survey was carried out through books, journals, articles, conference proceedings, unpublished dissertations and the internet to obtain basic and clear idea of in-housing and out-sourcing of facilities management services and identify existing decision making factors. .

2.1. FACILITIES MANAGEMENT IN GENERAL CONTEXT

Facilities management is gaining increasing recognition as a significant contributor to the overall effectiveness of many organizations in the world. FM offers an integrated approach in maintaining, improving and adapting the buildings and other infrastructure of an organization in order to create an environment that strongly supports the primary objectives of the organization (Barret and Baldry, 2003). Further, the International Facilities Management Association (IFMA, 2012) described FM as a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology.

In addition, Hinks (1998) argued that FM is indeed a means of contributing to the multidimensional enhancement of business competitiveness through the strategic management of built asset, rather than the cost efficient management of the built asset for the benefit of the business. From a strategic management perspective, Nutt (2004 cited in Chotipanich, 2004) observed that FM is the prime source for management of infrastructure resources and services with the focus to support and sustain the operational strategy of the organization overtime. On the other hand, Amaratunga *et al.* (2000) visualised FM as an umbrella term under which a broad range of property and user related functions may be brought together for the benefit of the organization and its employees as a whole.

In terms of scope of services, facilities management encompasses a wide-range of activities. Alexander (1996) observed that the scope of FM discipline covers all aspects of property and space management, environmental control, health and safety, and support services, and requires that appropriate monitoring and control centers are established in the organization. Binder (1989) sees FM as a field that incorporates many diverse functions including master space planning, space inventory, space and furniture standard settings, project management, programming requirements, financial control, purchasing, construction management, scheduling, layout and design and on-going maintenance management

The above perspectives show that the definitions and scope of facilities management and FM services could be wide-ranging. It was argued that "the differing definitions of facility management show that it is an evolving field whose nature is still somewhat fluid" (Hamer, 1988). It is therefore inadequate to formulate a holistic definition, which will capture the true essence and scope of FM functions. However, the above reviews provided some holistic insights into the wide spectrum of FM services upon which this research and the findings will be anchored.

2.2. CLASSIFICATION OF FM WORKS

From an administrative perspective, several authors (Then and Akhlaghi, 1990; Alexander, 1996; Chotipanich, 2002) classified facilities management works into three distinctive groups: strategic FM, ManagerialFM and operational FM. The Figure 1 illustrates the FM levels and characteristic of FM works in different level.

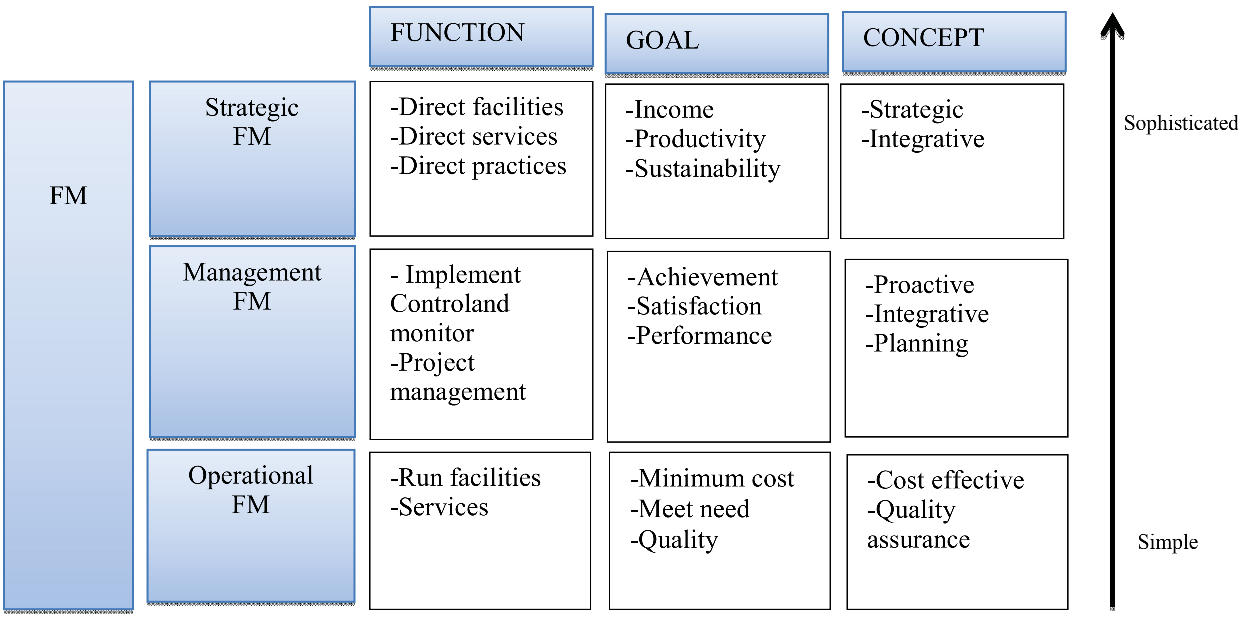

Figure 1: Characteristics of FM Works in Different Levels (Source: Chotipanich, 2002)

The strategic FM focuses on the receptiveness of the facility to the organization and business challenges; it concentrates on the complement between facilities and corporate objectives. On the other hand, the managerial FM works are basically emphasized on the organization and administration procedures (Kincaid, 1994). The scope of operational FM covers all types of daily and routine services on the workplace. It is further concerned with the effectiveness of the service functionality in an organization. However, Service levels begin with simple actions, easily carried out, and develop into sophisticated processes which are more difficult to implement.

Therefore, it can be concluded that these three disparate sets of complementary activities can be effectively performed with an impressive array of facilities management sourcing strategies which is best suit for the organizational FM functions.

3. SOURCING STRATEGIES OF FACILITIES MANAGEMENT

Atkin and Brooks (2005) emphasize that facilities management functions may be successfully performed or provided either by in-house or out-sourcing approach, depending on the priority of the activities or services of an organization.

3.1. IN-HOUSE SERVICE PROVISIONS

In-house approach is essentially referred to as a service that is provided by a dedicated resource directly employed by the client organization, where monitoring and control of performance is normally conducted under the terms of conventional employer / employee relationship; although internal service-level agreements may be employed as a regulating mechanisms (Barret and Baldry, 2003). Further, Atkin and Brooks (2002) emphasized the retention of the organization's employees for the delivery of estate related and facilities services are considered as in house service provision. The in house provision is characterized by the following (Luciani, 2005):

a. vertical integration within the organization of processes and production;
b. permanent teams of employees assigned to job specific tasks; and
c. Direct employment by the organization.

Advantages of in-house provision of FM functions

Wise (2007) insight to the benefits of in-house provision of FM functions:

- People who are in-house own their work. In-house employees usually will perform better than outsourced employees who make decisions based on how they will affect their own employers, not the people for whom they are working by proxy.
- Results of long-term financial analysis usually support in-house rather than outsourcing option.
- In-house option leads to improve the level of employee as well as customer satisfaction at the same time.
- In-house solution offers the company the opportunity to grow people instead of hiring from outside, and so provide career prospects that reduce staff turnover.
- Outsourcing could enable the organisation to pick the best service provider in terms of experience, quality, speed and efficiency. However, these may be quick fixes which are not sustainable in the long run.

Disadvantages of in-house provision of FM functions

Atkin and Brooks (2005) provide insight on the disadvantages of in-house provision of FM functions:

- A poorly defined scope will lead, almost inevitably, to problems in the management of the service with higher supervision costs and lowering of customer satisfaction. Consultation with all stakeholders is essential.
- Without delineation of roles and responsibilities, it can be difficult to measure the performance of in-house personnel.
- Given that the organization's management may be looking periodically at the market for external service provision, it makes sense for the in-house team to operate in business like way so that it can compete fairly if the need arises

- One of the biggest threats to the success of the in-house team is from complacency, which is easily noticed by customers.

3.2. *OUTSOURCING SERVICE PROVISIONS*

The term Outsourcing considers the involvement of an external party to the management role of facilities. Barrett and Baldry (2003) has used the term contracting out for the same and defined contracting-out as the generic term to describe the process by which a user employs a separate organization (the supplier), under a contract, to perform a function, which could, alternatively, have been performed by an in house staff. Outsourcing is generally characterized by (Luciani, 2002):

- individual service providers along a company's value chain;
- contingent and 'portfolio' workers assigned on a project-by-project basis; and
- Spot transactions and contracted procurement.

Advantages of outsourcing

Fill and Visser (2000) concur that the decision to outsource enable organizations to achieve cost reduction, expand services and expertise, improve employee productivity and morale, as well as achieve greater potential towards sharpening corporate image. In addition, Wise (2007) opines that outsourcing enables organizations to select the best service provider on the basis of wide ranging experience, quality, and speed as well as performance efficiency. From a business perspective, Hill (1994) argued that outsourcing has a great potential in bringing a business-like approach to bear in areas which may have no run on traditional lines for a long time, introducing new ideas, technologies and new findings; providing attractive possibilities for existing and new staff with appropriate skills, upgrading assets and services as well as providing reduced costs through specializations and large scale economies.

Disadvantages of outsourcing

Several authors (Collings, 2007; McCray and Clark, 1999) listed the problems with outsourcing as follows:

- Outsourcing vendor unable to deal with volume of activities.
- Variance in work ethic between organization and outsourcing vendor.
- Outsourcing vendor might be unable to perform task in specified time and fail to produce contractual results.
- Inadequate contract performance measures and penalties.
- Lack of capability to deal with time management when associating with outsourcing vendor.
- Lack of flexibility.
- Contracts solely focus on cost cutting issues.

However, In Sri Lankan commercial building context, some organizations favour a totally in-house FM option while others literally contract out every service possible, yet others use a combination of both; is depend on the priority of the activities or services of an organization. Since, both in-house and outsource facilities management have unique abilities to contribute to the achievement of best value for money.

4. CRITERIA FOR EVALUATING VALUE ADDITION IN FM FUNCTION

Through the literature survey, ten factors were identified as decision-making factors for sourcing strategies in facilities management. Table 1 shows Comprehensive evaluation criteria in clarifying value addition in FM functions. These factors act as success factors as well as to assist in determining the best decision on whether to retain services in-house or out-source them.

Table 1: Criteria for Evaluating Value Addition in FM Function.

Criteria	Description	Reference
Cost	The total cost of the contract including all self-performed and subcontracted specialist services.	Adler (2000); Kremic *et al.* (2006)
Quality	The service levels as defined in Service Level Agreements or other contractual or specified input or output structures.	Hubbard (1993); Kriss (1996); Kremic *et al.* (2006)
Risk and Liabilities	The degree to which the effective cost of the contract may vary to either party.	Usher (2004); Kremic *et al.* (2006)
Specialization and diversity	Many functions within an outsourcing contract are occasional rather than full-time equivalent roles of a specialized and marginal nature.	Hill (1994); Blumberg (1998); Lankford and Parsa (1999)
Responsibilities and accountabilities	The complexity and clarity of specific and general roles and assigned duties within and for the contract.	Hubbard (1993); Usher (2004)
Flexibility	The potential and ability to action changes in the nature, magnitude, resource, location and focus of the service delivery when required.	Drtina (1994); Kremic *et al.* (2006)
Innovation	The degree to which newly designed or conceived processes, methods, solutions or products are brought to bear within the outsourcing contract.	Blumberg (1998)
Investment	In respect to the agreed length and determined stability of the contractual relationship, the degree to which time and money are dedicated to improvements in, and development of the scope and facets of the service delivery.	Blumberg (1998); Usher (2004)
Information	The nature, format and validity of data, qualitative and quantitative, determining performance and metrics in relation to the provision of the services, and the regularity and manner of presentation of this information for the benefit of both client ad supplier	Usher (2004)
Customer Orientation	The degree to which the provision of the services understands and responds to the specific needs of the customer at all levels, in support of its business in relation to its own customers and shareholders, its management and staff, and those persons interacting with the business on a regular basis.	Blumberg (1998); Usher (2004)

The factors given in Table 1 provides strategic guidance in choosing between outsourcing and in-house approaches to providing part or whole of FM services in Sri Lankan commercial buildings. This ensures taking into consideration a wider range of key variables underpinning value-adding selection – a marked departure from the current practice of concentrating only on financials to the exclusion of other equally important variables that add value. Hence these factors provide the basis for making the optimum value adding selection in facilities management services.

5.1. Framework for Value Adding Selection between Outsourcing and In-House FM

Based on this literature survey, a conceptual framework was developed by incorporating the key variables to be considered in choosing between outsourcing and in-house FM in order to provide value-added services and to improve organizational performance. In this study, the criteria that add value to FM function as gleaned from the literature could be identified within the three broad respective facilities management functions; namely the strategic FM functions, management FM functions and operational FM functions. Each group may have its own unique value adding criteria that collectively contribute to the value added facilities management function (see Section 3.2)

Figure 2 represents the fundamental process in making rational decision in choosing between outsourcing and in-house approaches to meeting whole or part of FM needs. The process starts by comprehensively identifying vital FM functions that need to be performed in the organization such as strategic, management and operational FM functions and each functions compared with the value adding criteria include cost, quality, risk and liabilities, specialization and diversity, responsibilities and accountabilities, flexibility, innovation, investment, information and customer orientation. Subsequently, the levels of suitability of the use of outsourcing and in-house approaches to meeting each criterion under each subset of FM functions could be analysed. According to that, most suitable sourcing strategy could be selected for each FM functions.

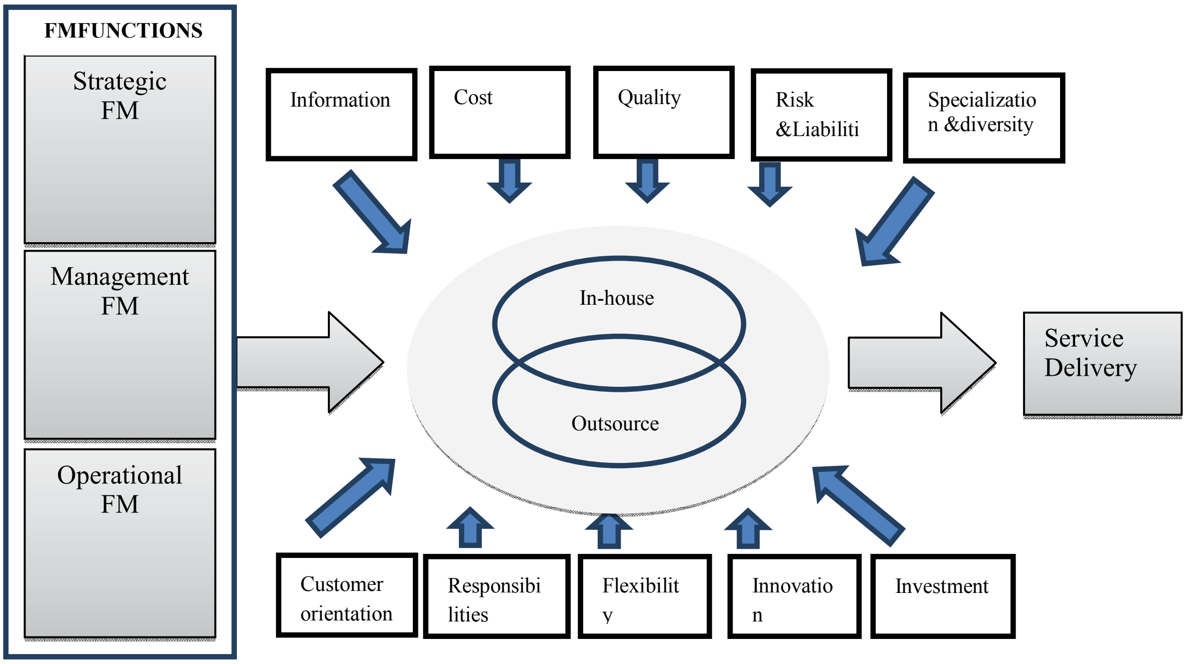

Figure 2: Frameworks for Value Adding Selection between Outsourcing and In-House FM

Above conceptual framework was developed for use by property and facilities managers in making a strategic choice between outsourcing and in-house approaches to providing part or whole of FM services. The conceptual framework ensures that wider criteria, other than costs, are considered, which underpin value addition in the provision of FM services.

6. WAY FORWARD

This study aimed to identify the criteria underpinning value-adding facilities management (FM) service, compare outsourcing and in-house approaches in terms of their value-adding capabilities in providing the components and sub-categories of FM functions, and subsequently establish a conceptual framework for choosing between outsourcing and in-house FM routes. Outcomes from the literature review show that the criteria for assessing value addition in FM services include cost, quality, risk and liabilities, and other criteria listed in Table 1. However, notwithstanding the above criteria for assessing value addition as gleaned from the literature, other equally important criteria might exist, especially those that were identified through the international literature. Therefore, this study will explore additional criteria used by client organizations in assessing value addition in FM services. In addition, the empirical study will be conducted by adapting qualitative research approach, which would lead to in-depth study and better understanding of selection between outsourcing and in-house FM services for the commercial buildings of Sri Lanka.

7. CONCLUSIONS

Facilities management (FM) is a major function in a business organization and it should be procured in an effective way in order to create an environment that strongly supports the primary objectives of the

organization. In house option and outsourcing option are identified as major means of procuring facilities management while they have inclusive secondary options. In order to achieve the strategic objectives of an organization it should consider the best options for procurement of FM and select the effective approach which is best suited for the particular functions. A framework was developed, which provides strategic guidance in choosing between outsourcing and in-house approaches to providing part or whole of FM services. This ensures taking into consideration a wider range of key variables underpinning value-adding selection – a marked departure from the current practice of concentrating only on financials to the exclusion of other equally important variables that add value.
The study recommends the use of the framework in making strategic choices between in-house and outsourcing in providing part or whole of the FM services by the facilities managers, property managers and other stakeholders who may be faced with the dilemma of choosing between outsourcing and in-house approaches to providing FM services.

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INTEGRATED FACILITIES MANAGEMENT PRACTICES IN SRI LANKA: A PRELIMINARY INVESTIGATION

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ABSTRACT

In this era of globalisation and fierce competition amongst businesses, most companies around the world faces relentless pressure to reduce cost, add value and support business goals for sustainability. Hence, innovative ideas, concepts and methodologies are needed to meet these demands. Integrated facilities management is one such concept, which extended beyond the traditional firm boundaries by enforcing external relationships. Few researchers have identified formation of networks, partnerships, or inter-organisational collaborations among neighbouring built environments as successful mechanisms in optimising the performance of facilities management (FM) functions. Although it is commonly agreed that organisations could benefit from integrated FM, a systematic framework for integration of FM functions has yet to be derived. Therefore, there is a need to investigate existing integrated FM practices and the applicability of integrated FM concept to built environments. The aim of this study is therefore is to review the concept of integrated FM and to investigate the existing integrated FM functions in Sri Lanka. The aforementioned research question was approached through a multiple case study including four cases that have integrated building facilities and FM functions with another organisation/s. Data was collected using observations and semi-structured interviews with facilities managers in the respective organisations. The findings revealed that if the firms are in close proximity, although the core businesses are same or not, there is a high potential of sharing physical facilities and FM functions among the firms. There is also a possibility of integrating FM functions among distantly located facilities when,(i) they are under same ownership, (ii) there is a close relationship between organisations or (iii) they obtain the service from outsourced FM service provider. The findings of this study will be useful in integrating FM practices in Sri Lanka.

Keywords: *Integrated Facilities Management (FM); Shared Facilities; Shared FM Functions.*

1. INTRODUCTION

Globalisation has forced local businesses to create and adapt global best practice procedures in order to compete in the world marketplace (Roger, 2004). In order to offer greater value for the core business in this competitive business environment, facilities management (FM) has to be well equipped with specialists, standards, advanced technologies and sophisticated systems. Nature and characteristic of FM profession are likely to be varying based on core business prospects and the range of services that they provide. Chotipanich (2004) noted that organisations are differently reliant on their facilities and support services. In turn, the function, role and scope of facilities management need to be aligned with organisational goals.

Further, it is evident that instead of conventional isolated organisations, collaborative approach has been contributed for gaining value for money as a realistic solution. In particular, the need for an integrated approach for FM could be considered as one of the sustainable solutions to built environments. Moreover, formation of network and strategic partnering enable solving most of the competing issues in FM, while delivering excellent services to the stakeholders. In this context, two or more cluster of firms, agree to integrate FM functions by creating a facilities zone could be one of the most favourable and sustainable approaches to FM.

Although it is commonly agreed that organisations could benefit from integrated FM, a systematic framework for integration of FM functions has yet to be derived. Therefore, there is a need to

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investigate the existing integrated FM practices and the applicability of integrated FM concept to built environments. Thus, this paper aims to:

- Review the concept of integrated facilities management
- Investigate the existing integrated FM practices and ability to implement the concept to Sri Lankan built environment

The paper structure begins in the following sections with a review of literature on facilities management and its functions, integrated FM, application of integrated FM to different built environments. The next section presents the conceptual framework developed for exploring integrated FM practices in Sri Lanka. Section 4 presents the research methodology followed by case study findings in Section 5. The paper finally presents discussions and conclusions of the study.

2. LITERATURE REVIEW

2.1. FUNCTIONS OF FACILITIES MANAGEMENT

Facilities Management (FM) is a profession with a wide scope. According to Becker (1990) facilities management is coordinating all efforts related to planning, designing, and managing buildings and its systems, equipments and furniture to enhance the organisation's ability to compete successfully in a rapidly changing world. Nutt (2000) identified the resource management at strategic and operational levels, as a primary function of FM. Further to the author, resource management comprises management of resources such as financial, physical, human, information and knowledge. Wiggins (2010) defined FM as a management function concerning three interrelated elements of business, i.e. premises, support services and information technology. Authors further identified following aspects under each element.

- Management – strategy or 'the thinkers'
- Operation – implementation or 'the doers'

FM researchers and practitioners express facilities management as a multidisciplinary area of development and opportunity (Tobi, Amaratunga and Noor, 2013, Chotipanich, 2004 and Grimshaw, 1999). However, the rapid growth of academic literature shows an expansion of interdisciplinary and organisational boundaries of FM. In this context, some researchers have introduced new concepts such as integrated facilities management (Kincaid, 1994), formation of strategic alliances (Pitt, Werven and Price, 2011), collaboration of infrastructure services (Cant, 2005), district oriented FM (Meneghetti and Chinese, 2002) and industrial symbiosis (Meneghetti and Nardin, 2012), which break traditional firm boundaries to share building facilities and management functions among organisations. Therefore, in recent years, it has become apparent thatthere is a clear shift towards integration of facilities and FM functions among organisations. The next sub-section reviews key literature on integrated FM concept.

2.2. INTEGRATED FACILITIES MANAGEMENT

Atkin and Brooks (2009) stated that there are common themes and approaches to FM such as in-house, outsource and a combination of in-house and outsource, regardless of the size and location of buildings. FM units deliver either in isolation or as an integrated function, which is a mixture of financial, asset and operational management activities, aligned to support the organisation's core business (Rogers, 2004). Tay and Ooi (2001) highlighted the importance of using an integrated approach for practicing FM in order to optimise the performance of FM functions.

Kincaid (1994) argued that FM activities can be coupled with knowledge in order to provide effective solutions to built environments. Operational activities, management roles, facility knowledge and management knowledge were identified as the major part of integrated facilities management. In order to integrate FM functions effectively, Kincaid (1994) proposed the following three (03) key characteristics that must be recognised by an organisation.

1. Facility management is a support role within an organisation, or a support service to an organisation,
2. Facility management must be linked strategically, tactically and operationally to other support activities and primary activities to create value, and
3. Within facility management, managers must be equipped with knowledge of facilities and management to carry out their integrated support role.

Further, Alexander (2003) stated that effective partnerships create an environment for optimum service delivery. Pitt, Werven and Price (2011) carried out a case study in aviation sector in order to explore the use of strategic alliances for facilities management. Strategic alliances are common in airline companies (James, 1999), where Vyas, *et al*. (1995) defined strategic alliance as an agreement between two or more partners to share knowledge or resources, with an aim to deliver a benefit to the parties involved. Airports generally outsource FM service to specialists. However, the current trend in airport management is the formation of a network structure with cooperation between two airports or between an airport and a third party for managing facilities (Pitt, Werven and Price, 2011). Further to Pitt and his co-workers, it is evident that FM in airports can be benefited from the use of strategic alliances and could be a method that FM can use to bring about organisational change to take advantage of changing external environment. Strategic alliance would enable FM to spread the risk of testing new technologies such as energy management and integrated building management systems among organisations. The authors have concluded that a strategic alliance between FM service providers, suppliers and building occupants could be an effective method to deliver organisational objectives.

Cant (2005) investigated the effectiveness of collaborating infrastructure services in regional retail centres using facilities management at the Birmingham Bullring, UK as a case study. In retail centres, infrastructure technology and facilities management needs to support a wide variety of retailer and visitor expectations. Therefore, Cant (2005) introduced four interlinked and interdependent trends for effective collaboration of infrastructure in order to meet investor expectations. Those four shifts are:

1. *Genuine collaboration and management integration* – encourage a mutually interdependent mini-economy, city centre management and incorporate FM and infrastructure as an implicit part of centre operation,
2. *Getting much closer to coalface* – investors getting closer to the retailers, use portfolio approach for property management, and focused and active management of the assets,
3. *Re-engineering of management of regional shopping centres* – restructuring to provide the capability to cross-resources and aggregate on a pan-portfolio, small centre management, and FM providers introducing innovation and experimentation at all levels of a retail shopping centre portfolio, and
4. *Embracing both strategy and detail* – building and maintaining more integrated working relationships, FM providers to understand the regional shopping centre market and respond accordingly, and focus on quality of the service at every level.

Furthermore, Meneghetti and Chinese (2002) analysed the possible evolution of FM in industrial districts, with special emphasis to Italian industrial system. Pyke and Sengenberger (1992) defined industrial district as a geographically determined productive system, performed by large number of firms who are involved at various stages and in various ways, in the production of the same product. Considering the technical and physical features of industrial districts from an external observer's point of view, Meneghetti and Chinese (2002) identified the following two dimensions of industrial districts.

- level of homogeneity in service demand, and
- physical proximity of firms

Authors further mentioned that service demand of different firms can be homogenous or heterogeneous, while their physical proximity can be high or low. Meneghetti and Chinese (2002) proposed "aggregation matrix" considering all possible combinations of events leads to clustering industrial district firms. The proposed aggregation mix is shown in Figure 1.

	Physical Proximity	Physical Distance
Homogeneity	Centralised facilities and management	Replicated facilities and polices
Heterogeneity	Distributed solutions	Specific facilities and management

Figure 1: The Aggregation Matrix for Facilities Management in Industrial Districts
(Source: Meneghetti and Chinese, 2002)

Firms with similar requirements located in close proximity can offer technical conditions for centralisation of some facilities and management functions. This scenario is highlighted by Clara (1998) through the research on central effluent treatment plant in Arzignano for the leather manufacturing district and by Karunasena and Kannangara (2012) through the research on effective waste management system by integrating all factories in one of the free trade zones in Sri Lanka. Meneghetti and Chinese (2002) found that it is difficult to implement centralised facilities and proposed replicated facilities and policies to assist effective facilities management for the firms with homogeneous demand but located in physically long distance. The authors further proposed distributed solutions for industrial districts with heterogeneous demand but located in close proximity, and specific facilities and management policies for industrial districts with heterogeneous demand and relative physical isolation from other organisations. The study revealed that cluster of organisations together conducting FM functions can be more proactive and beneficial to all the parties.

Meneghetti and Nardin (2012) noted the benefit of integrating FM functions through industrial symbiosis. Chertow (2000) defined industrial symbiosis as engaging "traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity". Meneghetti and Nardin (2012) concluded that the role of enabling industrial symbiosis can be played by a FM provider, when it embraces a district-oriented FM approach. They further highlighted the importance of moving from traditional solutions for single organisation to technical solutions specifically designed for clusters of firms.

3. Conceptual Framework for Exploring Integrated FM Practices in Sri Lanka

Meneghetti and Chinese (2002) and Meneghetti and Nardin (2012) proposed an effective model for optimisation of facilities management functions in industrial districts. However, there is a lack of study of integrated FM functions in non-district-oriented scenarios. Thus, this study broadens the borders of industrial clusters however use of the aggregation matrix and the following two dimensions proposed by Meneghetti and his co-workers as the basis for this research.

- Distance between organisations
- Nature of core business

From the past research, it was evident that firms could exchange some of the FM functions and facilities. The main focus of this study is therefore to explore the ability to integrate the following two aspects in-built environments.

- Integration of physical facilities among organisations
- Integration of facilities management functions among organisations

Sharing of facilities and related management functions with other firms is mostly depending on the ability of top management to create strategic alliance, nature of business, demand and supply of resources. The study investigates the possible exchanges of physical facilities and FM functions among firms, in order to add value to the core business. To optimise FM function, limitations for integration, economies of scale and scope have to be explored.

The aim of this study is therefore to investigate the impact of distance between organisations and the nature of core business in integrating physical facilities and FM functions among organisations in Sri Lanka. The conceptual framework developed for the empirical study with this aim and based on the literature review is shown in Figure 2.

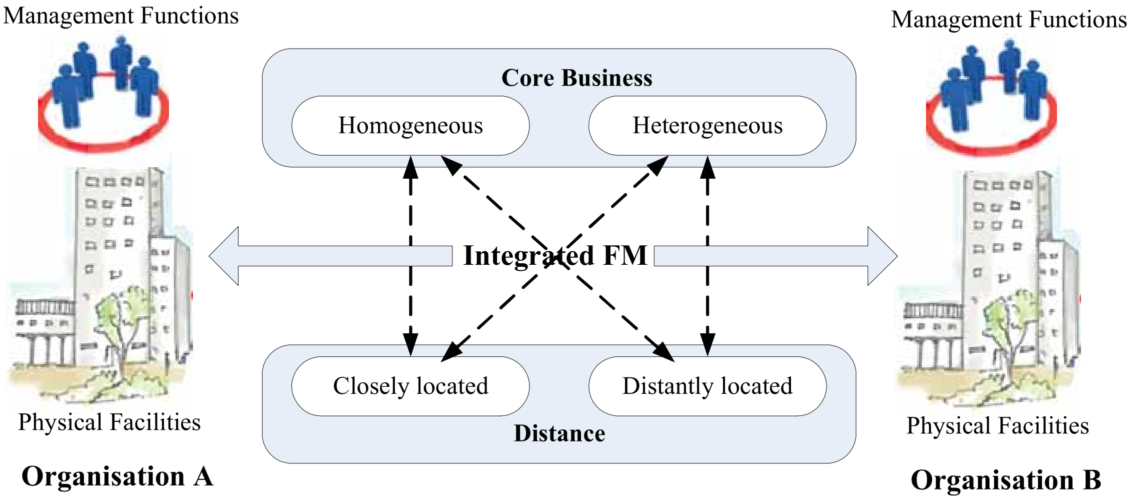

Figure 2: Conceptual Framework

4. METHODOLOGY

An extensive literature review was carried out to investigate FM functions and to explore the ability to integrate facilities and related functions. It is further expected to gain a better understanding about existing FM collaborative approaches. In addition, the review facilitated the development of a conceptual framework for empirical study. The study then carried out multiple case studies to explore the current integrated FM practices in the Sri Lankan context. Observations and semi-structured interviews with corporate level facilities managers, who have experience in integrating FM functions, were used as the data collection methods in the study. One case study from each quadrant of Figure 3, which has integrated physical facilities and/or FM functions was selected for the data collection.

		Distance	
		Closely located	Distantly located
Core Business	Homogeneous	Case Study –A	Case Study –B
	Heterogeneous	Case Study –C	Case Study –D

Figure 3: Selection of Case Studies

The next section presents the building facilities and FM functions that are integrated in the above four cases.

5. CASE STUDY FINDINGS

5.1. CASE STUDY - A

Organisations selected for the case study - A are located in close proximity and have similar core business function. Case study - A is an industrial zone with six factories. The industrial zone is around 165 acres and separated as industrial, training and leisure, and accommodation. Five of the factories are subsidiaries of the same parent company and their core business is garment production. Six industrial factories obtain several facilities and FM functions from centralised system located in the zone, from an agent of one service provider. The shared facilities and FM functions in the zone are given in Table 1 and the integrated system is shown in Figure 4.

Table 1: Shared Facilities and FM Functions in Case Study - A

Physical Facilities	Management Functions
Steam distribution system	Facilities management knowledge and skills
Water distribution system	Operational and maintenance standards
Wastewater treatment plant	Sustainability guidelines such as ISO-14000
Electricity distribution system	
Fire prevention system	

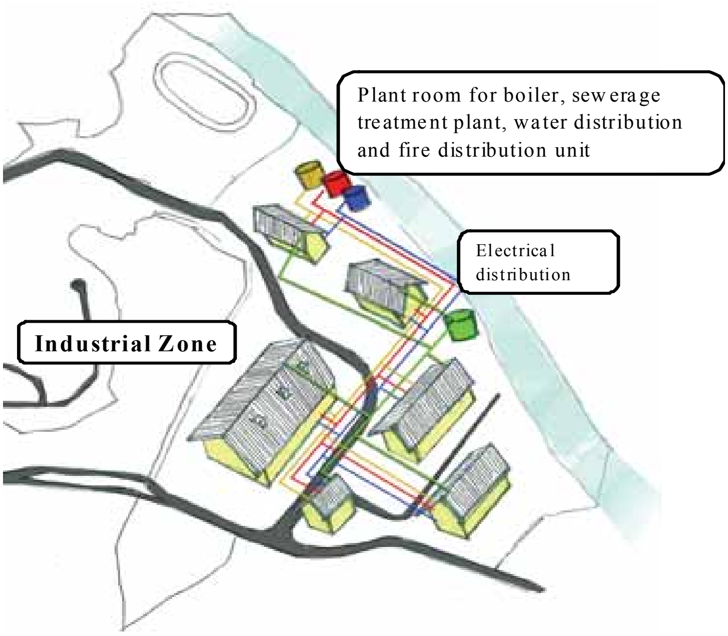

Figure 4: Integrated System in Case Study - A

The other building facilities and FM related functions such as heating and ventilation of factories, security, cleaning, health and safety, and catering are decentralised. The original design of industrial zone with centralised infrastructure and service distribution system facilitated the integration process of aforementioned services.

During the interviews, one Facilities Manager mentioned that "contracts for service level agreements and maintaining trust between each party are essential requirements to sustain the system". They further stated that "often communication and monthly meetings are essential for maintaining relationship between the service provider and the factories". The factories frequently review performance of the FM service provider and use customer feedbacks to enhance their service efficiency. Managers further highlighted that "*low operational and maintenance cost, less expenses for technical staff, less number of highly technical staff and simple business structure encourage the integrated approach. However, factories must agree on certain regulations for successful implementation of centralised system*".

5.2. CASE STUDY – B

Case study - B focused on of two garment factories with same core business located in two different geographical locations. The location layout of factories and their shared functions are shown in Figure 5.

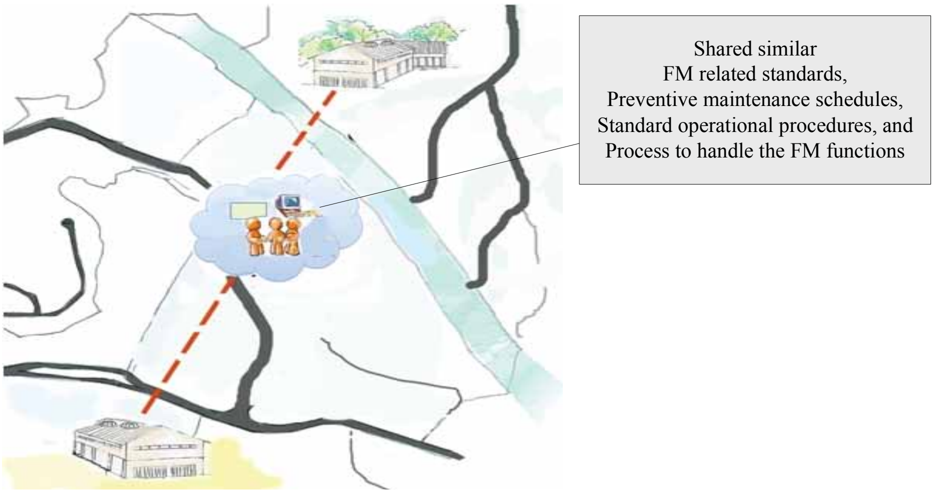

Figure 5: Integrated System in Case Study - B

Both selected factories are managed by one-parent Company. However, both factories consist of separate in-house FM team. Case study found that both factories follow a same FM related standards, preventive maintenance schedules, standard operational procedures, and a similar process to handle the FM functions. Consequently, FM mangers in both factories are also in collaborative approach to perform the FM operation. One Facilities Manager stated that "*discussions and sharing information are often carried out among managers to maintain similar process of FM between two factories*". He further mentioned that "*due to the geographical distance, factories are not able to share the operational functions of FM and physical resources*". It is also noted that collaborative approach at strategic level is high among the factories. As being subsidiaries, the factories have less restrictions and limited conflicts over integration of FM functions.

5.3. CASE STUDY – C

The case study - C focused on two organisations with different core business activities, however located in close proximity. One selected facility for this case study is a 39 storey high-rise commercial building, where as the other one is a 17 storey hotel. The organisations are two different legal entities having two separate FM divisions. The location layout of both buildings and their shared facilities are shown in Figure 6.

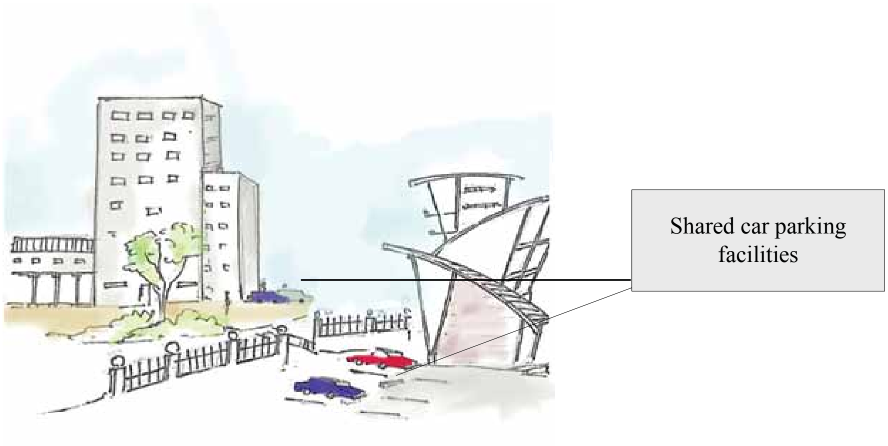

Figure 6: Integrated System in Case Study - C

Commercial property operates from 8 a.m. to 6 p.m. Managers in the commercial organisation noted that space available for car parking for their tenants and customers is insufficient during day time, which is the peak time for their business. However, during the night, the same car park is abandoned due to low demand from tenant. In contrast, it is found that hotel car park slots are available during daytime, however the hotel management is unable to satisfy car parking demand during night due to large number of guests demanding for lodging, attending banquet functions and having dinners. Considering the situation, two FM mangers from both parties have agreed to share car parking facilities in two premises. The agreement was to allow using the car parking slots in the other facility, whenever their parking slots are filled.

Facilities Manager of the commercial property said, "*due to the nature of operations in both businesses, our demand on car park varies. However, due to this decision, problem of insufficient car parking has been solved. Also, the Corporate Management is happy on the decision of integration. The decision adds value to the customer*." Although both organisations realised the benefits of integrated facilities, it is observed that they are reluctant to integrate further FM functions or facilities. Facilities Manger of the hotel facility said that, "*The existing regulations restrict the integration of facilities such as utilities. There should be a win-win situation in order to integrate the FM functions. Factors such as mutual trust between parties, transparent agreements and involvement in top management are essential to conqueror the integrated situation.*"

5.4. CASE STUDY - D

The buildings selected for case study - D are designed for two different core businesses and also located in geographically distance. One building is a multi-story apartment complex with over 1000 apartments and the other facility is a 39 storey two towers for commercial purposes. However, both the properties are invested and managed by one of the premier property developers in Sri Lanka. The property developer has their own FM division and hence, facilities management functions of both properties are managed by the division. Therefore, it is noted that two entities share several FM functions. The location layout of both buildings and their shared facilities are shown in Figure 7.

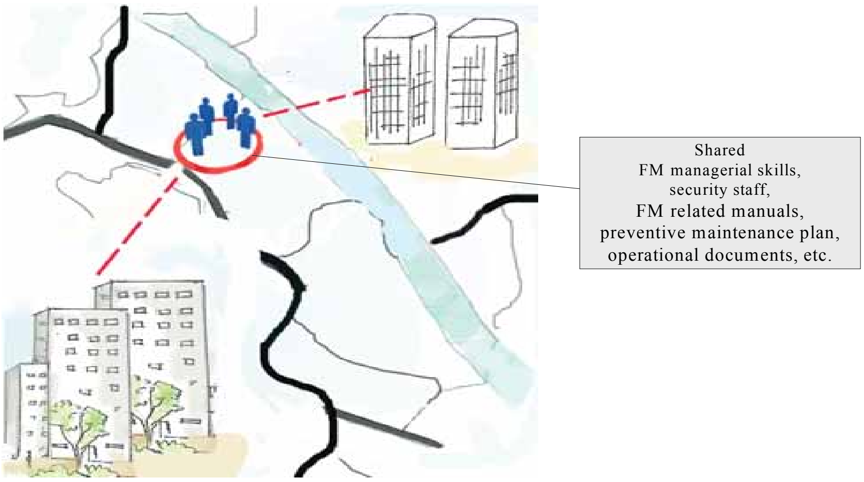

Figure 7: Integrated System in Case Study – D

The Facilities Mangers in both business entities are facilitating core business operations. It is also observed that both entities are sharing security staff. One Facilities Manager mentioned that "*in case of deficit situation of one entity, surplus security staff of the other entity will be moved to that entity to satisfy the demand. However, there is no conflict situation of sharing resources. We are not sharing other physical resource such as property and equipment as it belongs to the separate entity whereas staff is managed under our organisation*". Therefore both entities are sharing human resource such as facilities management skills and security skills, as being managed by sole FM service provider. Hence, FM related manual, preventive maintenance plans and operational documents are similar in both entities due to the collaborative approach. However, managers in FM division mentioned that "*distance between two entities restricts the integration of physical resources*".

6. ENABLERS AND BARRIERS FOR FACILITIES INTEGRATION

There are enablers and barriers for facilities integration that need to be addressed to gain competitive edge. During the interviews with Facilities Managers in the above organisations, they have identified owner's and manager's commitment, mutual trust, infrastructure arrangement, close proximity between facilities and similar nature of core business as enablers of integrated FM. Further, they have mentioned cost of facilities integration, different nature of core business, long distance between facilities, operating hours, different expectations of service delivery as the main barriers for FM integration. These barriers are lowering the opportunity of integrating facilities. Barriers of distance between facilities can be overcome by outsourcing FM functions to an expert organisation. Further, it is viable to integrate facilities and FM functions among neighbouring facilities at the inception stage of an investment project.

7. DISCUSSION AND CONCLUSIONS

Organisations implement FM as a tool to overcome their workplace problems, while enhancing the value of core business. The rapid development of management concepts and technologies forced organisations to implement innovative FM strategies. Integrated FM is a novel sustainable approach for any of the orgnisations to meet the core competencies of the business environment.

Preliminary investigation through case studies and discussions with FM experts have revealed that there are examples of integrated physical facilities and FM functions among the built environments in Sri Lanka. Nevertheless, it is evident that there is a less motivation for integration of FM due to several reasons.

If the firms are in close proximity, there is a high potential of sharing physical facilities and FM functions among the firms. It is easy to integrate facilities and functions, if the organisations are in same core business as the service requirement and the pattern of demand is equal. Case study findings revealed that industrial zone facilitates integration of both physical and management functions related to facilities management. Further, there is a high potential of integrating physical facilities such as electricity distribution, water distribution, wastewater treatment, fire prevention and detection systems, and waste management systems, and FM functions such as FM operations and maintenance, FM knowledge and skills, and FM polices and standards among organisations in the same core business and located in close proximity. However, mutual trust between parties is essential for successful implementation of centralised FM system. Although the core business is different, there are possibilities to exchange facilities and FM functions among neighbouring built environments. Facilities can be shared, when one facility has a surplus or deficit to match with the other party. When the owner or FM service provider is same, there is a great opportunity for sharing physical facilities and FM functions.

On the other hand, there is a high potential for integrating FM functions among the distantly located facilities, which have close relationships such as same ownership or same FM service provider. Facilities management knowledge and skills, security service, catering, cleaning and janitorial services are some of the FM skills and functions that can be integrated among distantly located organisations. Further, FM policies and standards also can be shared among organisations.

The study identified owner's and manager's commitment, mutual trust, infrastructure arrangement, close proximity between facilities and similar nature of core business as enablers, and cost of facilities integration, different nature of core business, long distance between facilities, operating hours, different expectations of service delivery as barriers for FM integration.

Therefore it can be concluded that there is a high possibility of integrating building facilities and FM functions among businesses when, (i) they are in close proximity, (ii) they are under same ownership, (iii) there is a close relationship between organisations or (iv) they obtain the service from outsourced FM service provider. With the emergence of the facilities management profession, there is a great potential to integrate building facilities and management functions in Sri Lanka. Sustainable integration of facilities and management functions will enable organisations to achieve strategic objectives and meet the expectations of the stakeholders.

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OVERCOMING SUSTAINABILITY ISSUES THROUGH FINANCIAL RISK MANAGEMENT IN PRIVATE FINANCE INITIATIVE PROJECTS

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ABSTRACT

The sustainable procurement is the process in which the sustainable needs are achieved by balancing against the business needs while considering enhancing the values through entire lifecycle of the product, waste reduction and recycling. Among the sustainable procurement approaches, Private Finance Initiative (PFI) is one of them, which is bringing together the public and private sectors to work together in partnerships to best utilize the assets and skills of both sectors with the aim of creating better value for money for taxpayers while initiating the projects with funds of private sector. However, the risk which is in adverse and uncertain by nature leads to sustainability issues in PFI procurement. Project finance (PF) refers to situations where the loan for the project is repaid from the future cash flows of the project. Project finance has been used wide for financing infrastructure and public sector facilities like hospitals, power stations, prisons, etc. Financial risk as the impact on the financial performance of any entity exposed to risk. Therefore, there is a need to minimize the financial risk in PFI projects. Accordingly, the aim of the study was to emphasis on overcoming sustainability issues on project financing through better financial risk management for PFI projects in construction sector. Comprehensive literature review was conducted to identify the tools and techniques. The study was developed to provide step by step details in identifying and analyzing the key risks and mitigation procedures in sustainable way at particular project phase. Then the gaps were identified and the opinions to improve the sustainability were identified.

Keywords: *Construction Industry; Private Finance Initiative; Risk Management; Sustainable Procurements.*

1. INTRODUCTION

Private finance Initiative (PFI) is a type of Public-Private- Partnership (PPP) where project financing rests mainly with the private sector. It seeks to combine the resources of the private sector with the public sector in order to provide a more efficient service to the public (Akintoye *et al.,* as cited in Yatanwala *et al.*, 2009*).* Involvement of private sector skills has been able to brought great advantages for developing economies by providing better value for money. According to Ogunlana (as cited in boussabaine, 2007) the major attraction in using private financing is that developing economies can meet their infrastructure needs without having to pay for the projects. As such, it is perceived in many quarters as a great solution to the infrastructure problem of the developing economies.

The long term and high value nature of PFI contracts leads to an increased focus, commitment and rigor to the application of good procurement practice such as governance models; contract management processes and the adoption of output specifications. This increased focus also spreads to sustainable procurement practice (CIPS, 2008). Green Alliance (2004) stated that The Private Finance Initiative (PFI) can and should be used as a lever to transform the construction sector in the UK towards greater sustainability of its products and practices.

Risk by its nature of adverse can be linked with the sustainability issues causing imbalance to the Social, Economic or environmental aspects and prevent achieving each parties objectives. The environmental risk like pollution, destruction can cause harm to the society and the environment as well. Many of the other risk in construction such as Time overrun cost overrun, quality issues, political risks, financial risks, natural disasters, market and the operation risk leads to the economic unbalance

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and the waste of important resources.

Merna and Njiru (2002) have defined financial risk as the impact on the financial performance of any entity exposed to risk. Horcher (2005) stated that Financial risk arises through countless transactions of a financial nature, including sales and purchases, investments and loans, and various other business activities. The economic climate and markets can be affected very quickly by changes in exchange rates, interest rates, and commodity prices. Counterparties can rapidly become problematic. As a result, it is important to ensure financial risks are identified and managed appropriately.

2. SUSTAINABLE PROCUREMENT

Sustainability refers to meeting the needs of present without compromising the ability to meet the future generations. It depends on how well it is achieved the balance of social, economic and environmental objectives when making decisions on today. The sustainable procurement is defined as "A process whereby organizations meet their needs for goods, services, works and utilities in a way that achieves value for money on a whole-life basis in terms of generating benefits not only to the organization, but also to society and the economy, whilst minimizing damage to the environment". The definition emphasize the environmental, social and economic aspects of process including the design, material used, manufacturing, logistics, logistics; service delivery; use; operation; maintenance; reuse; recycling options; disposal; and suppliers' capabilities to address these consequences throughout the supply chain.

Kennard (2006) identified that the sustainable procurement taking into account the following factors

- Entire life cycle cost of the product. We need to get away from the cheap throwaway society. You only need to look at the number of electrical/electronic commodities which you possess where the cost of repair makes it easier to replace and take up landfill space
- Quality required by the specification, bearing in mind the sustainable issue. These need to be both client driven and through the ethical procurement values of the suppliers
- Availability of the product
- Functionality of the product in the environment to which it is to be applied
- Effect the product will have on the environment when in service. We need to reduce the impact of our actions on future generations by radically reducing our use of resources and by reducing environmental impacts.
- Labor conditions of the producer and the human rights of the workforce. We should have regard for others who do not have access to the same level of resources and wealth generation.
- Use of sustainable or recycled materials and/or products.
- Reduction of waste. This not only helps to minimize the use of valuable resources, but also drives better business economics

2.1. PFI AS A SUSTAINABLE PROCUREMENT

Many arguments can be illustrated as strengthening the point that PFI meets sustainability standards also with the conflicting views. The long term high value nature of the PFI along with the consideration of the whole life aspects, the aim of providing better value to money, good contract management process increase the sustainable practice. CIPS (2008) stated that following points strengthen the argument

- The rigorous business case and review process required for PFI leads to a clear focus on the projects objectives including sustainability
- PFI encourages a focus on the whole life cost of the asset. With payments being linked to performance over the life of the contract the private sector must consider costs over the whole life of the contract to obtain funding and provide an acceptable return

- Given that the cost of running most assets over a 25 year period will be many times the capital cost it makes financial sense to invest at the front end in design solutions that will be efficient and result in lower running costs
- PFI's greater focus on risk identification, assessment and allocation results in sustainability issues being accurately identified and managed by the party most able to effectively manage the sustainability issues

PFI's are inflexible and once set on their course are difficult, and expensive, to change thus providing an obstacle to the introduction of more sustainable technologies as they emerge over the course of the contract. For example a study produced by the London Assembly in December 2007 argued that rigid PFI contracts had resulted in on-site renewable energy systems not being installed on schemes. Including the £600m Barts and Royal London hospital project

- There is often little incentive for the private sector to consider energy efficient systems as the payment for energy used frequently remains the responsibility of the public sector
- The PFI bidding process may not encourage innovative solutions that deliver sustainability. It is often commented upon that even where it is stated in the tender that innovative solutions are encouraged the belief amongst bidders remains that in practice innovation will not be rewarded in the tender evaluation process
- There may be reluctance on the part of the private sector to use new technology which they have none or limited experience of as they do not start to receive payment until the facility is operational and they may be fearful of delay.

3. RISK AND THE SUSTAINABLE ISSUES

Risk by its nature of adverse can be linked with the sustainability issues causing imbalance to the Social, Economic or environmental aspects and prevent achieving each parties objectives. The environmental risk like pollution, destruction can cause harm to the society and the environment as well. Many of the other risk in construction such as Time overrun cost overrun, quality issues, political risks, financial risks, natural disasters, market and the operation risk leads to the economic unbalance and the waste of important resources.

Risk management is an important element of the PFI, given the four inter-related principles at the heart of the UK PFI, i.e.: genuine risk transfer; output specification; whole life asset performance; and performance-related reward to the contractor. PFI demands that as much as possible the risks involved in PFI schemes including the design and construction risks are transferred to the Private sector. The fact that operational risks that traditionally rested with the client are now transferred to the private sector through PFI has implications for how projects are managed. (Akintoye and Chinyio, 2005)

The main advantages of the improving sustainability are in line with the ultimate objectives of the risk management and can be illustrate as below (ECFA, 2001).

- Reduced risks – less likelihood of health, safety and pollution incidents; reduced instances of delay and conflict during construction; reduced risk of public relations problems
- Protected and enhanced reputation – protection or enhancement of the client's reputation; better relationships with regulators; preferential status on bids
- Reduced or avoided costs – reduced operational costs through efficient use of materials, designing for energy efficiency and low maintenance, and good control systems; opportunity to employ flexible building systems capable of accommodating future requirements
- Increased opportunities to generate revenue – possibility of increasing usable floor area as a result of integrated design and reduced building service requirements, resale of demolition materials.

Financial risk in the PFI projects therefore can be considered as issues prevent achieving goals of the PFI project performance. The benefits of the better financial risk management and the improvement of the sustainability can be offset in same way. Environmental commodity financing, green building development, social responsibility investment funds and environmental risk insurance concerns the environment aspect while the Investing in capital gaps in disadvantaged communities and underserved markets and Micro-credit financing in developing countries can be considered as example for developing social factor. Providing better value for investors and the off take purchasers provide improvement of economic aspect.

4. PRIVATE FINANCE INITIATIVE

PFI is a type of PPP where project financing rest mainly with the private sector. The initiative represents the strategy through which government contracts to purchase quality public sector service on long term basis from the private sector, and includes maintaining and possibly constructing the necessary infrastructure. PFI is fundamentally about the delivery of service rather than the procurement of construction assets. (Hardcastle and Boothroyd as cited in Akintoye *et al.,* 2003)

One of the crucial premises for its adoption is that this new approach delivers better value for money and achieves better risk management. The PFI enables the private partner to build a facility to the output specifications agreed to with the public agency, operate the facility for a specified time period under a contract or franchise with the public sector client and then transfer the facility to the latter party when the contract expires. (Akintoye and Chinyio 2005)

Aziz (2001) stated that there are three categories of PFI projects

1. Financially Free standing Projects: the private sector undertakes the design, build, finance, operation and maintenance of the asset. The revenue streams may comprise fees paid directly to the consortia by users. (E.g. toll road fees).
2. Services sold to the public sector: fees paid by government on behalf of all potential users (e.g. fees per hospital patient serviced).
3. Joint Ventures: PFI projects are met partly from the public funds and partly from the private funds, with overall control of the project resting with the private sector.

4.1. FINANCIAL PLAN OF THE CONCESSIONAIRE IN PFI

Since the project is initiated with private finance, private sector holds the large portion of responsibility of raising the finance to the project. Source of funds to the concessionaire consist of debt and equity supplied by the depositary institutions (e.g banks) investors, insurance companies, mutual funds, pension funds, venture capital government and other agencies.

Each source of funds has its cost and other characteristics such as priority of payment, tax deductibility and so on. Establishes firms tend to fund projects through retained earnings (Atkin and glen, 1992)

A general model of the structure of the project financing is shown in below figure

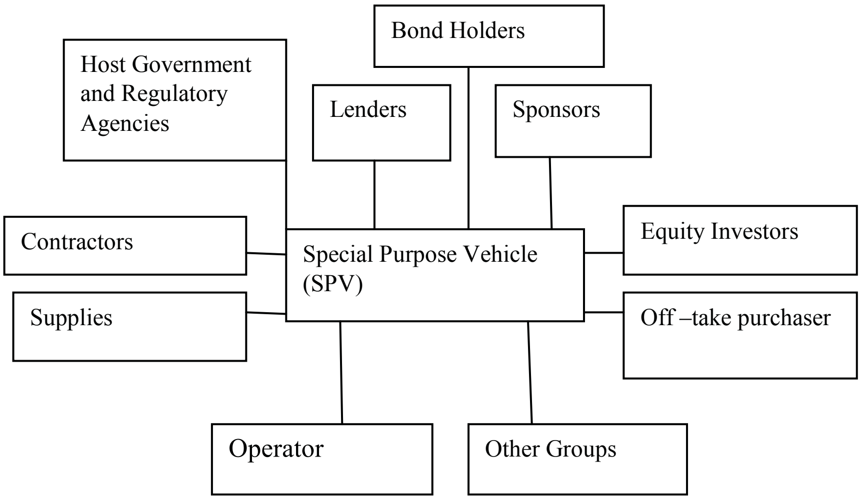

Figure 1: The Structure of the Project Finance
Source: Tan W., (2009, p.213)

There are many variations to this basic model for instance bonds may not be issued in a project, and lenders may include international lending agencies such as the World Bank and Asian Development Bank. Further each party may assume several roles for example, in addition to its regulatory role; the state may also be the supplier of inputs (e.g.: oil) as well as off –take purchaser of the project output through another agency such as State Electricity board in the power projects.

In pure non- recourse project financing, only project assets and cash flows are used for loan repayments this makes non-recourse lending risky. Lenders are often compensated by the opportunity to lend substantial sums of money on lucrative projects. In limited recourse financing parent companies of project companies provide some form of contingent financial support over and above their equity share as well as other forms of credit enhancement and third-party guarantees (Willie, 2007). The financial flow of the PFI project can be identified as flows.

4.2. METHOD OF FINANCING THE PFI SCHEME

Project finance (PF) refers to situations where the loan for the project is repaid from the future cash flows of the project. Project finance has been used wide for financing infrastructure and public sector facilities like hospitals, power stations, prisons, etc. Project finance originated from America where these schemes were introduced to finance the exploitation of Texan oil reserves (Leeper, 1979). These schemes were set up because project sizes were growing larger and entrepreneurs could not provide sufficient collateral for any bank loans.

Finnerty (1996) noted that the specific features of the PFIs allow SPV members to finance their projects by reference to the ultimate service purchaser's credit rating. This possibility positively impacts on the financing structure of PFI as well as the degree of leverage involved in the respective financial setups. However, the possibility for low cost finance can be offset is there are high contractual costs and, in particular high legal expenses (Beck and Darinka, 2005). In order to satisfy the capital requirements PFI project usually has to depend on several source of financing while the main source being external financers, sponsors provide some portion of equity to show their commitment.

(Akintoye *et al.,* 2001) has carried out survey on PFI financial structure. A total of 48 elite interviews were conducted with PFI participants from the public sector, the private sector and independent consultancy companies (incl. legal, technical, insurance, etc.). Among the private sector companies 10 leading financial organizations. Findings emphasized that the financial structures of PFIs depended very much on the type of the operational 'envelope' and the interaction between the main parties.

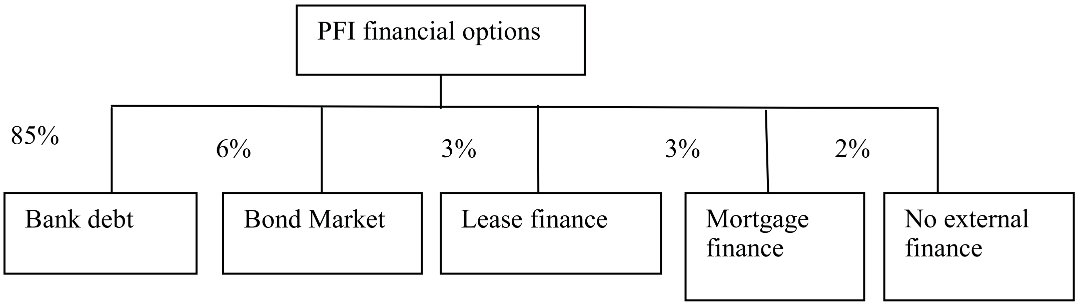

Figure 2: Sources of Project Finance
Source: Akintoye *et al.* (2001)

According to the experience of our respondents the main financing options for PFIs included, i.e. bank debt (85%) and bonds finance (6%). These were usually combined with sponsors' equity (Figure 1). More rarely, respondents noted the use of lease finance (3%), mortgage finance (3%) and financing without external contributions (2%).

The capital comes with associated costs. Equity is the lowest ranking capital layer of the PFI project and, in case of project failure, the equity investor therefore likely to bear the highest risk of loss. Due to the high risk equity carries highest rate of return where as the debt holders have the priority over the equity investors when the payment is made. Spate, (As cited in Akintoye *et al.* 2003) has identified the number of factors which determines the ability of SPV s to limit their equity contribution to the total capital requirement. The main factors include economic consideration, cost attached to the equity, requirements of the jurisdiction of the SPV, government requirement and the lenders requirement.

Initially, at the emergence of the PFI market, the financing options were very limited and the major capital requirements were met by the traditional PF methods, i.e. through of bank debt. However the market demand and the affordability issues required the creation of alternative approaches. In recent years more sophisticated capital market products have been developed to provide long term debt at competitive conditions in respect of credit terms and margins (Morrison 1998; Middleton and Richardson 1999). Thus the popularity of fixed income products such as bonds has grown significantly. Banks, meanwhile, have responded to the new challenges by extending the maturities beyond the traditional20-23 years and lowering the margins (Ellis, 1999)

Different financial institutes such as pension funds and life insurance provide fixed rate financing for PFIs while commercial banks often provide floating rate financing. In addition to the equity there are number of financing options available such as bond market, commercial lending through bank debt, leasing, mezzanine debt and mortgage finance, etc(Sapte, 1997; Ellis, 1999; Pickering, 1999)

Finnerty (as cited in Akintoye *et al*, 2005) distinguishes between four alternative types of bank credit, which include revolving credit, term loan, standby letter of credit or performance bond and bridge loan. Revolving credit provides the sponsor with the opportunity to use a line of credit repeatedly within certain limits as project needs arise. The term loan is a fixed time loan over more than one year, which is used to cover the capital costs during the project's construction period. The stand by letter of credit or performance bond imposes an obligation on the issuing bank to make payments to commercial paper holder. Finally a bridge loan is a form of interim financing covering the time lag before the expenditures are covered.

The loans are popular in PFI projects as the repayments are covered by the profit of the SPV. In large transaction borrowing requirements are often financed by several banks through a syndication agreement. In this context, the underlying financial structure is usually arranged by a single bank, which subsequently sells parts of its loan to other banks. Syndicate banks are often long –term partners, which lend at the same conditions and have the same priority for repayment. The syndicator, meanwhile, is usually a lead banker and investment manager who keeps a small amount of the whole loan (Akintoye *et al*, 2005).

Mezzanine debt is relied upon the cases where there is a gap between senior debt and sponsors equity. The situation typically arises when senior debt providers are not prepared to increase the level of debt and the sponsors cannot invest more equity. This can be due to the small size of equity provided by the sponsors or specific project circumstance (Morrison, 1998). In such cases, mezzanine finance provide by other parties outside the SPV can bridge the short fall by providing a third layer of capital in the range of up to 20%, in the form of subordinated debt (Morrison, 1998). Normally, Mezzanine finance is exposed to greater risks and higher returns compared to the senior debt. It also ranks ahead of equity n terms of payment distributions, and is therefore more akin to equity than to senior debt. However, due to the higher risk being carried by equity, equity typically provides for the highest potential returns. Therefore the attractiveness of Mezzanine finance to the investor thus arises from the fact that it provides for the possibility of achieving good commercial returns with excessive risk being taken.

A PF lease involves fixed term lease contracts between large financial institutions (lesser), which own the assets for tax purposes, and the SPV (lessee), which pays the agreed series of payments. The lesser is entitled to depreciation allowances, which are normally not available to the SPV due to the lack of trading income (Sapte, 1997). Mortgage finance refers to situation where the asset is owned conditionally by the SPV. The borrower has the rights to use the property while the mortgage is in effect and agrees to pay on a regular basis towards the principle and interest.

In addition to these sources there are other organizations by their nature collect and manage capital. These include life insurance companies, public pension funds and private pension funds. Public placement funds utilize funds which are collected from the retirement funds of the public sector employees in projects which meet set standard in terms of risk and return.

There is a direct relationship between the risk and the return for the financial components. Risk and return for main financial component used in PFI is illustrated in the figure.

Bonds are long term interest bearing documents of debt, issued by public sector as well as the private sector organizations, which oblige themselves to pay the principle amount after a specific period of time called maturity (Fitch, 1997). Banks, insurance companies and individual investors comprises the bond market in fact not all the organizations can issue bonds.

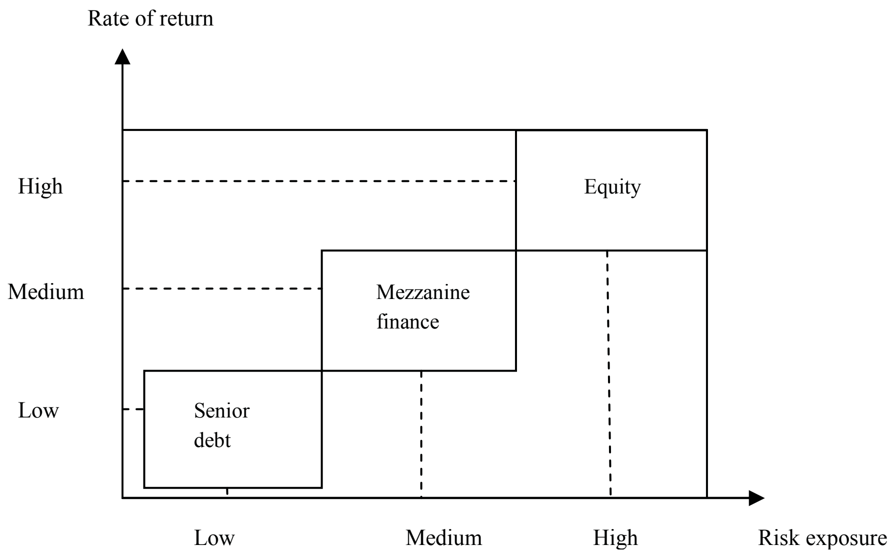

Figure 3: Relationship between the Risk Profile and the Rate of Return for Main Financial Components in PFI
Source: Akintoye *et al.* (2003, p.133)

4.3. REFINANCING PFI PROJECTS

The refinancing of projects involves changing the conditions on which a loan was initially provided. Refinancing of PFI projects has become possible only recently, due to the increased confidence in the financial markets towards PFIs. The refinancing is suitable for some earlier projects, where the construction had been completed and successful operation has been demonstrated. Therefore the risks to the project are substantially reduced. The key components of the refinancing may include changes in interest rates, repayment dates, margins and the level of senior debt (TTF, 1999), etc. Refinancing brings higher profits to the shareholders, but does not necessarily mean that the public sector can share the benefits. Capital markets are expected to play a significant role in the refinancing of PFI projects by providing efficient resources in terms of longer repayment periods, cheaper, and more highly geared debt.

5. FINANCIAL RISK OVERVIEW IN PFI

Risk management is an important element of the PFI, given the four inter-related principles at the heart of the UK PFI, i.e.: genuine risk transfer; output specification; whole life asset performance; and performance-related reward to the contractor. PFI demands that as much as possible the risks involved in PFI schemes including the design and construction risks are transferred to the Private sector. The fact that operational risks that traditionally rested with the client are now transferred to the private sector through PFI has implications for how projects are managed. (Akintoye and Chinyio, 2005)

Financial risk arises through the countless transaction of financial nature, investment and loans and other business activities. It can arise as a result of legal transactions, new projects, mergers and acquisitions, debt financing, changes in the market condition the energy component of costs, or through the activities of management, stakeholders, competitors, foreign governments, or weather.

Horcher (2005) identified three main sources of financial risk:

1. Financial risks arising from an organization’s exposure to changes in market prices, such as interest rates, exchange rates, and commodity prices
2. Financial risks arising from the actions of, and transactions with, other organizations such as vendors, customers, and counterparties in derivatives transactions
3. Financial risks resulting from internal actions or failures of the organization, particularly people, processes, and systems

Financial risk management is a process to deal with the uncertainties resulting from financial markets. It involves assessing the financial risks facing an organization and developing management strategies consistent with internal priorities and policies. Addressing financial risks proactively may provide an organization with a competitive advantage. It also ensures that management, operational staff, stakeholders, and the board of directors are in agreement on key issues of risk.

Major market risks arise out of changes to financial market prices such as exchange rates, interest rates, and commodity prices. Major market risks are usually the most obvious type of financial risk that an organization faces. Major market risks include:

- Foreign exchange risk
- Interest rate risk
- Commodity price risk
- Equity price risk

Other important related financial risks include:

- Credit risk
- Operational risk
- Liquidity risk
- Systemic risk

5.1. HEDGING AND CORRELATION

Hedging means making an investment to reduce the risk of adverse price movements in an asset. It the business of seeking assets or events that offset, or has weak or negative correlation to, an organization's financial exposures.

Correlation measures the tendency of two assets to move, or not move, together. This tendency is quantified by a coefficient between –1 and +1. Correlation of +1.0 signifies perfect positive correlation and means that two assets can be expected to move together. Correlation of –1.0 signifies perfect negative correlation, which means that two assets can be expected to move together but in opposite directions (Horcher, 2005).

5.2. DIVERSIFICATION

An asset's risk in isolation is greater than its portfolio risk whenever the asset's cash flows and the portfolio's cash flows are less than perfectly correlated. In this common place situation some of the assets cash flows variability in the portfolio's cash flows and the effective risk the investor bears is reduced (Higgins, 2000).

For many years, the riskiness of an asset was assessed based only on the variability of its returns. In contrast, modern portfolio theory considers not only an asset's riskiness, but also its contribution to the overall riskiness of the portfolio to which it is added. Organizations may have an opportunity to reduce risk as a result of risk diversification. In portfolio management terms, the addition of individual components to a portfolio provides opportunities for diversification, within limits. A diversified portfolio contains assets, whose returns are dissimilar, in other words, weakly or negatively correlated with one another. It is useful to think of the exposures of an organization as a portfolio and consider the impact of changes or additions on the potential risk of the total.

5.3. INTEREST RATE RISK

In contrast, interest rate will affect the project in terms of borrowing and debt payments. Any fluctuation in the interest rate will definitely affect the lenders. An appropriate interest rate should be agreed upon the project. The lenders have to pay extra cost if the interest rate is far high or benefit them if the interest rate is low (Bakar *et al.,* 2010).

Horcher (2005) found that Interest rate risk arises from several sources, including:

- Changes in the level of interest rates (absolute interest rate risk)
- Changes in the shape of the yield curve (yield curve risk)
- Mismatches between exposure and the risk management strategies undertaken (basis risk)

5.4. FOREIGN EXCHANGE RISK

Foreign exchange risk arises through transaction, translation and economic exposures and also from the commodity based transactions where the prices are trade in foreign currencies. Bakar *et al.* (2010) stated that Fluctuations in foreign exchange are considered another major risk which might affect the BOT project during the construction and operation. Foreign companies who are interested to invest in another country should aware of the opportunities and threats associated with international currency transactions before they proceed.

5.5. COMMODITY RISK

Exposure to absolute price changes is the risk of commodity prices rising or falling. Organizations that produce or purchase commodities, or whose livelihood is otherwise related to commodity prices, have exposure to commodity price risk. The revenues generate by SPV in the PFI contracts arises from the delivery of commodity or services while the most of the time commodity being energy products ex: Electricity, Gas, crude oil.

Commodity Price Risk

Commodity price risk arises when there is a possibility of changing the commodity price. Commodity exposure can also arise from the non-commodity business if the input or products and services have a commodity component. The risk can be offset by using fixed rate contracts commodity futures or forwards. In many projects government tend to assure the commodity prices by several ways. Tan (2009) stated that the price may be fixed beforehand, indexed or based on prevailing market prices. Price floors and caps may also be applied in hedging agreements.

Commodity quantity risk

This is relates to the demand for the services provided by the facility. In more recent PFI schemes public sector tend to bears the risk, so the private sector is less concern about the level of usage of the service. Thus, for example, in a prison project, the SPV will not be concerned if all the cells are filled or not, as that risk rest with the HM Prisons Service. However, some PFI schemes, by their peculiar nature, still tilt the demand risk to the private sector, as it is best placed to bear that risk in such circumstances (Akintoye *et al*., 2005).

5.6. *CREDIT RISK*

Credit risk or counterparty risk is one of the most prevalent risks of finance and business. According to Lam and Chow, credit risk as the risk that the counterparty (partner of the joint venture) to any financial transaction is not being able to fulfill its commitment on the due date. Horcher (2005) stated that the failure of counterparty is less of an issue when the organization is not owed money on a net basis, although it depends to a certain degree on the legal environment and whether funds are owed on a net or aggregate basis on individual contracts.

In a concession contract, transactions between two or more parties contain a risk that one party will default on an obligation of the commitment. Failure in financing the required cash flow for the BOT project is the most common issue that arises (Bakar *et al*., 2010).

5.7. *SOVEREIGN OR COUNTRY RISK*

Sovereign risk encompasses the legal, regulatory, and political exposures that affect international transactions and the movement of funds across borders. It arises through the actions of foreign governments and countries and can often result in significant financial volatility.

5.8. *CONCENTRATION RISK*

Concentration is a source of credit risk that applies to organizations with credit exposure in concentrated sectors. An organization that is poorly diversified, due to its industry or regional influences, has concentration risk. Many banks and organizations used investment from different sectors to diversify the risk.

5.9. *LEGAL RISK*

The risk that counterparty is not legally permitted or able to enter into transactions, particularly derivatives transactions, is known as legal risk. The issue of legal risk has, in the past, arisen when counterparty has suffered losses on outstanding derivatives contracts. A related issue is the legal structure of the counterparty, since many derivatives counterparties, for example, are wholly owned special-purpose subsidiaries.

5.10. EQUITY PRICE RISK

Equity price risk affects corporate investors with equities or other assets the performance of which is tied to equity prices. Performance of the concessionaire is crucial in seeking for fund to implement a PFI project. Usually, equity risk is related with the performance of the company which is measured by the share price of the company. The higher the share price goes, in definite, benefit the shareholder but the lesser it goes will affect the prestige of the concessionaire. Capability of the company in raising capital for the PFI project is reflected on the share price (Bakar *et al*., 2010).

5.11. LIQUIDITY RISK

It relates to ability to sell or purchase the security or obligation either for hedging purposes or trading purposes, or alternatively to close out an existing position. Liquidity can also refer to an organization having the financial capacity to meet its short-term obligations. Assessing liquidity is often subjective and involves qualitative assessments, but indicators of liquidity include number of financial institutions active in the market, average bid/ask spreads, trading volumes, and sometimes price volatility (Horcher, 2005)

(Bakar *et al*., 2010) identified that Most of the PFI project; the revenues are generated from the operation. To ensure the success of the PFI project, it should able to generate sufficient amount of revenue to settle the debt within the stipulated time frame. An amount of profit that can be generated from the operating facility is determined by conducting analysis on the projected revenue during operational phase. The failure to generate the required revenue will cause to liquidity risk.

5.12. EMBEDDED OPTIONS

Embedded options are granted to securities holders or contract participants and provide them with certain rights. The granting of permission to buy or sell something is an option, and it has value. For example, the ability to repay a loan prior to its maturity is an option. If the borrower must pay a fee to repay the loan, the option has a cost. If the loan can be repaid without a fee, the option is free to the borrower, at least explicitly. The value of the option is likely to be at least partially embedded in the interest rate on the loan (Horcher, 2005).

5.13. SYSTEMIC RISK

Systemic risk is the risk that the failure of a major financial institution could trigger a domino effect and many subsequent organizational failures, threatening the integrity of the financial system. Aside from practicing good risk management principles, systemic risk is difficult for an individual organization to mitigate.

5.14. COMMERCIAL RISK

Commercial risk is described as a risk that can jeopardize the financial performance to the project. In spite of that, commercial risk in BOT project is characterized differently; Merna and Njiru (2002) have classified into three categories, risks related to the completion, during operation and risks related to input or output of the project. Supply and off-take agreement between the supplier and the government is very crucial in mitigating the risk (Bakar *et al.,* 2010).

5.15. FINANCIAL RISK MANAGEMENT IN PFI

Darinka and Beck (2005) has conducted a research to identify financial Risk management techniques were most frequently used by the financial services providers involve in PFIs; the project team conducted 14 interviews with senior financial experts across the UK.

The sample of the financial companies for the survey included 14 leading financial organizations, based on operating in the UK, all of them with substantial records in PFI transactions. Senior representatives from all areas of financial engagement in PFI were interviewed.

Risk Identification techniques

The main risk identification methods used by the practitioners are illustrated in Figure 2.10. The result shows that they relied heavily on their previous experience in forming a broad initial judgment about the feasibility of the project. Furthermore, the later on in the PFI process the employment of consultants to investigate the risk details become more relevant.

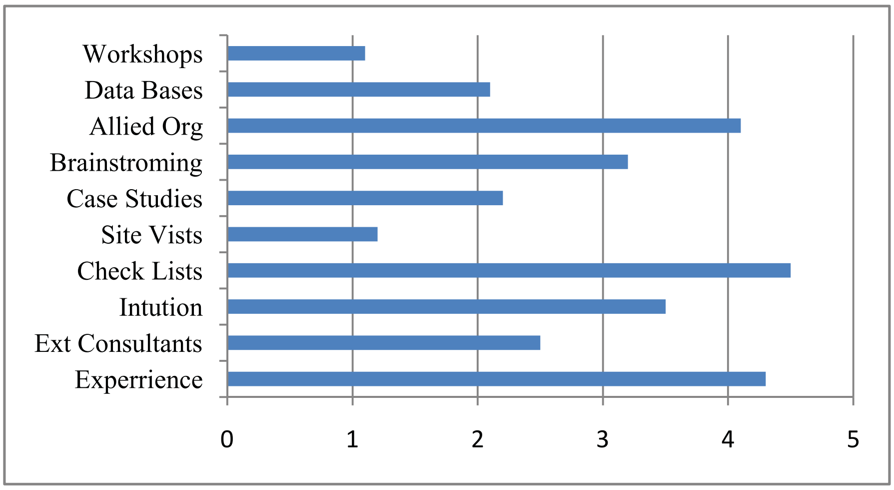

Figure 4: Top 10 Risk Identification Approaches Used by the Financiers in PFI Schemes
Source: Akintoye *et al.* (2003, p.139)

The financial model was their key risk assessment tool. It was a mathematical expression of the project's future cash flows, which included all project revenues and costs, as well as taking account of the risk factors affecting them. One of the principle goals of the model was to estimate financial impact of the different risk through semi-quantitative analysis. The financial model was then used to investigate different 'what if' scenarios, which could include anything from an increase in operational costs, raising inflation, construction delays, and pessimistic life cycle scenarios.

Risk Mitigation Practices

Risk mitigation can be categorized into four different forms: acceptance, reduction, avoidance and transfer (Flanagan and Norman1993). Many strategies can be found to mitigate the financial risk. Darinka and Beck (2005) identified that regardless of their precise function in finance (as debt or equity providers), the risk mitigation practices of financiers were very similar, with the exception of situation where they acted as financial advisers only.

Risk Transfer

Responsibilities of the risk can be transferred to the other party who is willing to bear it, whenever is possible. According to the respondents, a bank can deal effectively with financial risks but, from a senior lender's point of view, the margin in this type of projects is in the range of 1%,i.e. the bank can afford to lose money in 1 of the 100 projects. As a consequence most banks seek to be fairly certain that most relevant risk have been passed on to other parties. In line with the idea of allocating the risk to other parties, financiers transfer all major construction risk to the construction companies, all operational risk to operational companies, while political and some legislation risk are transferred to the public sector (Darinka and Beck 2005).

Risk Retention

Financial organizations normally bear some risks which are related to their core activates as well as some residual project risks ex: Interest rate and inflation risk, the financial organization then used to offset this risk by hedging and derivatives. They also have to retain counter-party risk such as the credit risk, which is normally mitigated through a thorough investigation of the borrower's financial standing.

Risk Reduction

If not eliminated, risk can be reduced by acquiring more information. In view of their adverse consequence, and given that risk are inevitable, attempt should be made to minimize their effect.(Akintoye et al., 2005) Financial exposure can be reduced by interest rate swaps, which provide a fixed rate of loan repayment, as well as other hedging instruments which provide index-linked rates or interest rate caps.

Although basic types of financial derivatives have been known for decades, they have become a major feature of financial markets since the 1970. At that time, the development of derivatives accelerated by increased instability in financial markets in terms of exchange rates, interest rates and price fluctuations. The main types of derivatives include futures, options and swaps. In addition to these, there are numbers of new, more complex off- balance sheet financial instruments. In most cases, the latter can be de-composed to a basket of the main instruments (Akintoye et al., 2003).

The derivative is a contract between two parties that derives its value from some underlying asset price, index, or reference interest rate. Derivatives include forwards, futures, swaps, caps and floors and options (Willie Tan, 2009). The basic idea underlying the use of derivatives is provide protection against adverse price movements and rates by fixing their future transactional values (Blommestein, 2000).

6. CONCLUSIONS

Private Finance Initiative projects are considered as a sustainable procurement practice and have provided great advantages over the other practices in the construction industry in many countries. The long term nature of the PFI projects results that the few projects still have run to their full length and therefore less data available in long run. This and involvement of many parties in the process leads the projects high vulnerable to risk and uncertainty via the sustainability issues special in developing economies with small financial markets the financing for PFI projects need convincing for financial institutions of guaranteed return. However these issues can be overcome by better financial risk management aim towards the achieving sustainability. Incorporating sustainability aspects to existing risk management practices will result in better risk management in PFI projects.

Improving Sustainability of the risk management aims intended to ensure that environmental, social and economic (sustainability) issues are managed, understood and managed in all key procurement decisions that relate to the procurement of products. This involves the identification, assessment and mitigate of key impacts on the environment, society and the economy. Even the PFI procurement with aim to provide better value for money has shown a nature of sustainability procurement practice. The key financial risk embedded in the PFI structure should be identified. Yet there are no risk management framework supports to manage the sustainability risk as a key to achieving goals in financial terms. The innovative financing solutions is required reduce the risk and achieve sustainability in project financing. Financial Strategic planning, income diversification and improvement of financial administration is key to achieving sustainability in financing.

Some points could be suggested to improve the identification of sustainability issues and drive towards better financial risk management.

- Improvement of financial engineering with developing new innovative financial instruments aimed at improving sustainability practices.
- Stress by the legislation or by public sector that the preparation procedures include sustainability
- Instruments and options towards environmental risk and hazard reduction.
- Financiers concern towards the sustainable project development and social responsibility.
- Energy as a commodity can be subjected to commodity based derivatives to achieve better value for money.
- Social involvement in financing

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PLANT AND EQUIPMENT MANAGEMENT TO MINIMIZE DELAYS IN ROAD CONSTRUCTION PROJECTS

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ABSTRACT

Construction is the ultimate objective of a design, and the transformation of a design by construction into a useful structure which is accomplished through proper management of human, material, machineries and equipment resources. A project manager must insure that these inputs are effectively coordinated to achieve an efficient construction process. "Delay" in construction is a project slipping over the planned schedule and is considered as a common problem in construction projects. Plant and Equipment (P&E) management is a complex procedure in a construction project. Machines are to be selected, arrived on site, are used and, when a project is completed, removed and returned to the company's plant depot or the hire company. Within this cycle various decisions and assessments are required to be made. These are related to above challenges and delays due such could be affected directly or indirectly by poor P&E management. Hence, introduction of proper construction P&E management criteria helps in minimizing the confusion created due to the above problems and further to cut down monetary losses.

Therefore, this research aims to study the effects of improper P&E management on construction delays and to identify proper practices on P&E management to minimize delays. The paper discusses the theoretical background of the issue based on the findings of the comprehensive literature review done through refereeing to the published material. Research will be followed by a questionnaire survey to explore the situation within the Sri Lankan road construction projects as the field study. The data will be analyzed statistically in order to make conclusions and recommendations.

Keywords: *Construction Projects; Delays; Management; Plant and Equipment.*

1. INTRODUCTION

Construction is the ultimate objective of a design, and the transformation of a design by construction into a useful structure which is accomplished by human, material, machineries and equipment and proper management of those resources (Peurifoy, Clifford, and Shapira, 2006). According to Hendrickson (1998), good project management in construction project regularly continues the efficient utilization of labor, material and equipment. A project manager must insure that these inputs are effectively coordinated to achieve an efficient construction process altogether. This coordination involves both strategic decisions and tactical management in the field. Westland (2003) stated that a project has a clearly specified format and end date within which the deliverables must be produced to meet a specified customer requirement. Wherever such coordination is missing, delays in completion of the project can be occurred.

The project manager must also manage the plant and equipment assigned or used in the project (Reh, 2013). The use of new equipment, proper equipment and innovative methods has made possible changes in construction technologies in recent decades (Hendrickson, 1998). Therefore financial planning in construction companies tends to focus on decisions relating purchasing, leasing, depreciating, maintaining, repairing, and replacing equipment. One of the keys in success is the control of time, cost, and quality by the selection and use of the right equipment for the job (Day and Benjamin, 1924). Hence a relationship can be seen between P&E management and project duration.

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Assaf and Hejji (2006) stated, in construction, delay could be defined as the time overrun either beyond completion date specified in a contract, or beyond the date that the parties agreed upon for delivery of a project. Delays are considered as a common problem in construction projects. To the owner, delay means loss of revenue through lack of production facilities and rentable space or a dependence on present facilities. In some cases, to the contractor, delay means higher overhead costs because of longer work period, higher material costs through inflation, and higher labor costs.

The choice of construction equipment is determined on method of doing the work, the time to complete the work, and the cost of construction (Day and Benjamin, 1924). Therefore when there a shortage in selected plant and equipment force is occurred, it may influence on construction duration as well as the cost. Hence poor management of plant and equipment may be a considerable reason behind many of the factors. As Sharma (2007) stated, P&E manager should co-ordinate with various wings of the organization in discharging his job of equipment planning, balancing, selection of equipment, its deployment and its utilization, personnel selection and training, financial planning, preventive maintenance and general supervision. Thus, equipment management integrates and continuously interacts with human, technical, financial, and production system in order to achieve top efficiency and cost effectiveness. Like the other major resources, committed P&E are expected to be fully utilized to complete a project due time (Uher, 2003).

However, there could be number of factors affect to the delays in construction projects. P&E management is a major procedure in a construction project. Because of the complexity of this procedure, project time could be affected by poor plant and equipment management. Therefore this research addresses the issue of effects of poor P&E management on project delays.

2. PLANT AND EQUIPMENT MANAGEMENT IN ROAD CONSTRUCTION PROJECTS

Introduction of proper construction P&E management helps in minimizing the confusions created due to logistics management, horizontal/vertical transportation, material handling, execution methods, interruptions, delays, prolonged duration of projects, finishing trades, and infrastructure requirements (Mohideen, 2011). It is difficult to identify the limit to machine usage on construction sites. It is clear, however, that as time goes by more machines will be invented or adapted for use in the construction industry. Therefore management continually has to make decisions about methods of operation and the right mix of human and machines within a working environment. Machines are therefore selected, arrive on site, are used and, when a project is completed, removed and returned to the company's plant depot or the hire company. Within this cycle various decisions and assessments are required to be made (Canter, 1993). Therefore if these assessments and decisions are not made in proper manner, it will be difficult to face the challenges previously stated. That means proper management of P&E is essential for a successive completion.

Further, P&E management can be done in several ways. Various types of construction equipment can be grouped in several ways (Day and Benjamin, 1991). Mainly they could be classified as functionally and operationally.

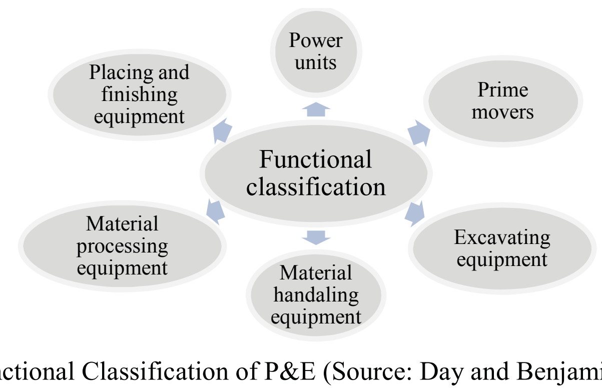

Figure 1: Functional Classification of P&E (Source: Day and Benjamin, 1991)

Operational classification is better in use (Day and Benjamin, 1924). Functional classification is done according to the functional activity of equipments as above.

According to Leuva (2012), to construct perfect roads, it is essential that there is adequate equipment for the construction work. Further, Campbell (2011) states that effective construction equipment management means being able to draw a definitive line between a losing company and one that is profitable and successful. Construction companies that are finding continued success even in the current economy who finds new ways to lower operating and maintenance costs, optimize their utilization, reduce downtime and increase profits. As per to Marvelous (2012) maintenance of construction equipment is crucial as this preserve them for future construction jobs, accident and save contractors from unnecessary expenses. Maintenance is not only thing to be aware of in P&E management. Selecting and planning proper equipments on specific construction tasks also a one of important proportions of that management criteria (Casals, 2005). Therefore management of these P&E is directly affects on project duration. All road construction activities comprised with P&E management part and, included in the critical path of a project mostly. Therefore management of these P&E is directly affects on project duration. Thus, in minimizing construction delays, it is very important to manage P&E in a proper manner.

Further, Edwards and Holt (2009) concludes that construction P&E management is embedded within the broader subject of construction management, representing a vibrant research field from which eight principal research themes have been identified as plant maintenance, downtime and productivity, optimization, robotics and automation, health and safety, operators and competence, machine control and miscellaneous.

3. Strategies and Best Practices for P&E Management

Construction management is a vast area that considers several components of a project. Direct involvement of P&E management is rare to be seen in these management strategies. However P&E practices can be categories as below.

- **Selection**

Contractors consider selection of equipment fleet a vital factor for any construction project to be successful. The task of the project planner, estimator or the engineer on the job is to select and match the right machine or combination of machines to the job at hand (Peurifoy, Schexnayder and Shapira, 2006).

Table 1: Best Practices for P&E Selection

P&E selection best practices	Reference
Use models based on traditional mass haul diagrams, artificial intelligence and genetic algorithm and geographic information system to crew optimisation	Mawdesley *et al*., 2004)
Mathematics of rough sets and fuzzy sets	Cirovic and Plamenac (2006)
Analytical hierarchy process to take account of qualitative factors	Goldenberg and Shapira (2007)

- **Acquisition**

Contractors have two options in acquiring plant. They may either own their machinery and equipment or hire it. Many contractors prefer to hire only those items of plant, which are required to meet peak demand or specialized activities. The alternative decision to purchase will have important financial consequences for the contractor, since considerable capital sums will be blocked up in the plant, which must be operated at an economic utilization level to produce a profitable rate of return of investment (Construction information services, 2012).

Table 2: Best Practices for P&E Acquisition

P&E acquisition best practice	**Reference**
Purchase equipment outright by cash, financing	Tavakoli *et al*. (1989)
Acquiring rental equipment	Tavakoli *et al*. (1989)
Acquiring leased equipment	Tavakoli *et al*. (1989)
P&E acquisition best practice	**Reference**
Purchase equipment in used condition, new condition, based on personal judgments, based on current and future workload, based on life cycle cost (LCC) of equipment, based on company financial status or based on internal rate of return (IRR) of investment	Prasertrungruang and Hadikusumo (2007); Schexnayder and Hancher (1981); Tavakoli *et al*. (1989)
Make decision on acquiring or disposing equipment by president/CEO, by board of directors, by equipment managers or by project managers	Hinze and Ashton (1979); Schexnayder and Hancher (1981); Tavakoli *et al*. (1989)
Purchase equipment based on brand popularity and spare parts availability, functions and its usage	Hinze and Ashton (1979); Prasertrungruang and Hadikusumo (2007)
Purchase the same brand that is being used regularly	Hinze and Ashton (1979)
Purchase equipment from familiar dealers	Prasertrungruang and Hadikusumo (2007)
Purchase equipment based on its price	Hinze and Ashton (1979)
Buy new or used machine based on budget availability	Prasertrungruang and Hadikusumo (2007)
Buy used machines because of cheaper price but still in good condition or need in functions and advanced technology	Prasertrungruang and Hadikusumo (2007)
Buy used machines only the ones that do not have complicated systems, ones that render expensive repair cost once failure, ones that do not have high repair cost once failure, ones that are not frequently utilized or ones that are frequently utilized for a long time	Prasertrungruang and Hadikusumo (2007)
Use rental or leasing strategy for the infrequent utilized equipment, to avoid equipment obsolescence, to avoid uncertainty of spare part cost, to avoid initially financial burden to the company, to test a newly launched machine, to save spare parts cost, to benefit from mechanics' learning curve, to lower operator/labour costs of machines or to enhance safety as operator uses similar machines	Hinze and Ashton (1979), Prasertrungruang and Hadikusumo (2007); Tavakoli *et al*. (1989)
Use standardization policy for better relationship with dealers or for easier equipment administration	Tavakoli *et al*. (1989)

- **Operation**

Stewart (as cited in Prasertrungruang and Hadikusumo, 2007) says an equipment operator is the person in the construction organisation who has the control on equipment costs. Quality output can be partly achieved through skilful operators working with machines that are in good operational condition, thus educating equipment operators is one of the most important policies and thus holds great cost-saving potential.

Table 3: Best Practices for P&E Operation

P&E operational best practice	Reference
Allow an equipment operator to work with more than one machine	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Provide training by in-house equipment department, equipment dealers or external agencies	Prasertrungruang and Hadikusumo (2007)
Consider poor operating procedures as a main cause of equipment accident	Tavakoli *et al*. (1989)
Consider poor maintenance as a main cause of equipment accident	Prasertrungruang and Hadikusumo (2007)

- **Maintenance**

P&E are exposed to a huge amount of abuse, dirt and various other elements which can cause damage of equipment if they are not cared for in the proper way. Maintenance of construction equipment is crucial as this preserve them for future construction jobs, accident and save contractors from unnecessary expenses and time (Mavelous, 2012).

Table 4: Best practices for P&E Maintenance

P&E maintenance best practice	Reference
Provide maintenance by equipment operators	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Provide maintenance by in-house equipment department	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Provide maintenance by equipment dealers	Hinze and Ashton (1979)
Provide maintenance by other external mechanics	Hinze and Ashton (1979)
Provide preventive maintenance programs to equipment	Tavakoli *et al*. (1989)
Seek for substitute equipment once machine suddenly breakdowns	Tavakoli *et al*. (1989)
Wait until the failed machine is completely repaired and ready for use	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Transfer crews to other works once machine suddenly breakdowns	Tavakoli *et al*. (1989)
Accelerate speed of works once machine suddenly breakdowns	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Modify project activity and schedule once machine suddenly breakdowns	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Consider poor operating procedures as a main cause of machine failure	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Consider poor maintenance and use of non-original parts as a main cause of machine failure during use	Tavakoli *et al*. (1989)

- **Disposal**

Douglas (as cited in Prasertrungruang and Hadikusumo, 2007) reports the last stage of machine lifecycle is disposal stage, in which two major decisions concerning equipment have to be made as timing of replacement and equipment economic life expectancy. Further Hinze and Ashton (1979) state that there are various factors affecting the timing of replacement as follows, machine efficiency, capital availability, investment costs, commencement of new projects, profits accrued from use, tax expense, depreciation, economic analysis, obsolescence costs, and downtime cost.

Table 5: Best Practices for P&E Disposal

P&E disposal practice	References
Dispose or replace equipment based on intuition and rules of thumb	Schexnayder and Hancher (1981);
Dispose or replace equipment based on equipment economic analysis	Hinze and Ashton (1979); Schexnayder and Hancher (1981); Tavakoli *et al*. (1989)
Dispose or replace equipment when it becomes technologically obsolete	Hinze and Ashton (1979);
Dispose or replace equipment when it becomes inefficient	Hinze and Ashton (1979);
P&E disposal practice	**References**
Dispose or replace equipment when the company financial status is good	Hinze and Ashton (1979);
Dispose or replace equipment before commencing a new job or project	Hinze and Ashton (1979);
Dispose or replace equipment before major overhaul with high repair cost	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Determine equipment economic life based on investment cost	Hinze and Ashton (1979);
Determine equipment economic life based on downtime cost	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Determine equipment economic life based on obsolescence cost	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Determine equipment economic life based on tax advantage	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Determine equipment economic life based on depreciation cost	Hinze and Ashton (1979); Tavakoli *et al*. (1989)
Determine equipment economic life based on maintenance and repair cost	Hinze and Ashton (1979);
Determine equipment economic life based on profit accrued from use	Hinze and Ashton (1979);

4. PROBLEMS IN P&E MANAGEMENT

When selecting equipment for a given job, the major challenge to be faced is to satisfying several constraints imposed by the job and the contractual obligations. These constraints or factors include, specific construction operation, job specification requirements, conditions of the job site, location of the job site, time allowed to do the job, balance of interdependent equipment, mobility required of the equipment and versatility of the equipment (Day and Benjamin, 1991). Further, in managing construction equipment, contractors are invariably plagued with several difficulties such as huge capital investment in the acquisition phase, which usually constitutes a major financial burden. Procurement of major construction equipment not only costs as high as 36 percent of the total construction project cost, but also causes a high delivery time uncertainty, which may disrupt the construction schedule (Yeo and Ning, 2006).

According to Stewart (as cited in Prasertrungruang and Hadikusumo, 2007), in the operational phase, contractors are often faced with problems relating to high rate of equipment breakdown and accident resulting from unskilled operator abuse. Poor training of equipment operators is often claimed as a major cause of equipment-related accidents (Gann and Senkar, 1998). In the maintenance phase, proper maintenance management of construction equipment is never over-emphasized since the cost and time that exceed the designated budget or schedule on projects are often resulted from poor machine maintenance practices. However, over-maintenance of equipment is undesirable as well (Vorster and De La Garza, 1990). Finally at the disposal phase, determining equipment economic life and timing for replacement is often problematic because such decision is influenced by various factors such as machine obsolescence and efficiency (Vorster and Garza, 1990).

5. POOR P&E MANAGEMENT AND CONSTRUCTION DELAYS

According to Alaghbari (2007), delay is generally acknowledged as the most common, costly, complex and risky problem encountered in construction projects. Because of the overriding importance of time for both the owner (in terms of performance) and the contractor (in terms of money), it is the source of frequent disputes and claims leading to lawsuits. In construction, delay could be defined as the time overrun either beyond completion date specified in a contract, or beyond the date that the parties agreed upon for delivery of a project. Hancher and Rowings (as cited in Alaghbari, 2007) stated that there is a wide range of views on the causes of time delays for engineering and construction projects. Some are attributed to a single party, others can be ascribed to several quarters, and many relate more to systemic faults or deficiencies rather than to a group or groups.

Generally, delays can be divided into three major types namely, excusable and non-excusable, compensable and non-compensable and concurrent (Alaghbari, 2007). According to Alaghbari (2007), compensable delays are those that are generally caused by the owner or its agents. Basically, non-excusable delays are caused by contractors or subcontractors or materials suppliers, through no fault of the owner. Excusable delays, also known as "force majeure" delays, are the third general category of delay. These delays are commonly called "acts of god" because they are not the responsibility or fault of any particular party. Most contracts allow for the contractor to obtain an extension of time for excusable delays, but not additional money. If only one factor is delaying construction, it is usually fairly easy to calculate both the time and money resulting from that single issue. A more complicated, but also more typical, situation is one in which more than one factor delays the project at the same time or in overlapping periods of time, these are called concurrent delays.

There are various causes for delay on above all categories. Therefore it is important to study causes for delays.

5.1. CAUSES FOR DELAYS

Many of researchers have considered causes for delay in every way can be. Among them, some delay causes can be identified directly and indirectly related to poor P&E practices. Some causes have been severely identified by more than one researcher as tabulated follow.

Table 6: Causes for Delays in Road Construction

Causes for delay	**References**
Poor site management and supervision	Chan and Kumaraswami (1997); Alaghbari *et al.* (2007); Assaf and Al-Hejji (2005); Ramanathan, Narayanan and Idrus (2012)
Improper control over site resource allocation	Chan and Kumaraswami (1997)
Shortage of material availability	Alaghbari *et al.* (2007); Ramanathan, Narayanan and Idrus (2012)
Shortage material supply	Ramanathan, Narayanan and Idrus (2012)
Shortage of plant/equipment	Chan and Kumaraswami (1997); Assaf and Al-Hejji (2005)
Delay in delivery of materials to site	Alaghbari *et al.* (2007); Assaf and Al-Hejji (2005); Ramanathan, Narayanan and Idrus (2012)

Causes for delay	References
Delays in sub-contractors work	Chan and Kumaraswami (1997); Assaf and Al-Hejji (2005); Ramanathan, Narayanan and Idrus (2012)
Delay in site mobilization	Assaf and Al-Hejji (2005);
Construction mistakes and defective work	Alaghbari *et al.* (2007);
Improper construction methods implemented by contractor	Assaf and Al-Hejji (2005);
Damage of sorted material while they are needed urgently	Assaf and Al-Hejji (2005);
Equipment breakdowns	Assaf and Al-Hejji (2005);
Low productivity and efficiency of equipment	Assaf and Al-Hejji (2005); Ramanathan, Narayanan and Idrus (2012)
Lack of high-technology mechanical	Assaf and Al-Hejji (2005); Ramanathan, Narayanan and Idrus (2012)
Low level of equipment-operators skill	Assaf and Al-Hejji (2005); Ramanathan, Narayanan and Idrus (2012)
Poor judgment and experience of involved people in estimating time and resources	Ramanathan, Narayanan and Idrus (2012)
Ineffective planning and scheduling of project by contractor	Chan and Kumaraswami (1997); Assaf and Al-Hejji (2005); Ramanathan, Narayanan and Idrus (2012)
Accident during construction	Assaf and Al-Hejji (2005)

5.2 RELATIONSHIP BETWEEN DELAY CAUSES AND POOR P&E MANAGEMENT

When considering the above studies, although authors have identified P&E related delay causes separately, also they have identified more causes under another categories where the causes are indirectly influenced by poor P&E management. For example, in Assaf's (2005) research, although P&E has been taken as a separate causes category, there are some causes identified in other categories also related to P&E. In material category, "Delay in material delivery" can be caused by poor management of transportation equipment. Also in contractor category, "Delay in site mobilization" is also related to transportation equipment. In same category "Delays in sub-contractors work", "Ineffective planning and scheduling of project by contractor" are also influenced by poor P&E management. Because, subcontractors also use P&E for their work component, and if P&E selection is not up to level needed, planning and scheduling goes wrong. Therefore by considering these facts, it is important to identify relationships between all causes imported in to table and poor P&E management.

In the table, according to 1st and 2nd causes, those can be related respectively to poor P&E allocation at the site and their poor operational management. 3rd and 4th causes can be influenced by poor transportation equipment management. "Shortage of P&E" (5) is identified as a direct cause for construction delay by Chan and Kumaraswami (1997) and Assaf and Al-Hejji (2005). According to above paragraph, 6th, 8th, 9th and 22nd causes are related to poor P&E management and, in 7th cause, it means that it is a delay in payment of rental of P&E. That may forms absence of P&E at such construction sites. Poor techniques and tasks of relevant P&E also can affect on 10th, 11th and 12th causes. Also 13th cause can be occurred due to use of non- suited P&E in transporting and handling material. "Equipment breakdowns" (14), "Low productivity and efficiency of equipment" (15), "Lack of high-technology mechanical" (16) and "Low level of equipment-operators skill" (17) are delay causes directly related to poor P&E management. In "Poor judgment and experience of involved people in estimating time and resources" (18), these resources may include P&E. Both "Poor economic conditions (currency, inflation rate, etc.)" (19) and "Difficulties in financing project by contractor" (20) can be affect on acquisition of P&E. "Conflicts in sub-contractors schedule in execution of project" (21) also can include poor P&E allocation of sub-contractors. 23rd cause

("Inadequate early planning of project") is formed by consultant's mistake. Due to that problem, contractor won't be able to plan their P&E appropriately. The last (24^{th}) delay cause ("Accident during construction") identified by Assaf and Al-Hejji (2005) and Ramanathan, Narayanan & Idrus (2012) is frequently happening in construction sites due to poor maintenance and operational management practices.

6. SUMMARY AND WAY FORWARD

Construction industry is a rapidly developing industry in Sri Lanka with the many projects which are currently on progress. At the same time, delays in completions can be seen frequently. There could be number of factors affect to the delays in construction projects. Plant and equipment management is a major procedure in a construction project. Because of the complexity of this procedure, project time could be affected by poor plant and equipment management. This research addresses the issue of poor plant and equipment management is effect on project delays.

Therefore this research aims to identify proper practices for plant and equipment management to minimize construction delays by studying the effect of improper plant and equipment management on those delays. In achieving this aim the objectives were set as below;

- Study the major causes for delays in construction projects and to identify the relationship between plant and equipment management and causes of delays.
- Identify proper practices to manage plant and equipment.
- Prepare a guideline to manage plant and equipment in a way of minimizing project delays.

The method for the research comprises an initial comprehensive literature survey which has been carried out through referring to books, journals and articles to obtain existing knowledge on various causes for delays related to plant and equipment management. Based on the findings of the literature survey, a questionnaire survey will be carried out to obtain views upon the factors affecting construction delays, their relationship with plant and equipment management and practices used to prevent each factor. Then statistical analysis will be carried out to rank the causes for delays most related to plant and equipment management according to the level of importance. Also proper plant and equipment management practices used to minimize delays will be ranked. Conclusions and recommendations will be carried out based on findings.

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PRIMARY STUDY OF THE IMPACT OF IN-SITU AND FACTORY PRODUCTS IN SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

In an environment of aggravating labour shortage, it is inevitable for the construction industry to face number of difficulties. Therefore it is essential to explore ways and means to develop less labour intensive products, and identify whether these provide real solutions in reducing time and cost with enhanced quality. Further, it is obvious that the current construction industry is in a dilemma with lack of knowledge on behaviour of those aspects. Contactors hesitate to use factory products as these products are expensive, even these would lead to time savings and reduction of labour requirement and also towards sustainability in construction through many aspects. Therefore the need for a comparison between in-situ and factory made products on time, cost and quality is a need of time.

This ongoing research mainly focuses on the usage of factory made and in-situ products based on the respective pros and cons. This was done by initiating a survey among various expertise in the industry. Further, prioritizing the most labour intensive products was very essential to identify what trade areas are the main concerns. Therefore the overall time, cost and quality aspects of in-situ products can be compared with correspondent factory products and identify the challenges on the contractors for using the effective alternatives.

This paper contains the preliminary findings of a literature review conducted on the use of in-situ and factory based construction components both locally and globally.

Keywords: *Cost; Factory Made; In-Situ; Labour; Quality Time.*

1. INTRODUCTION

Advancement of technology has led the construction industry to go beyond its boundaries. According to Albuquerque *et al.* (2011), today it searches for more innovations and demands more efficiency in the construction process and to minimize waste. Further, the emergence of off-site production is also similarly has a potential to address many industrial issues. When the fear of skill shortage embraced the construction industry which wholly depends on its work force, many researchers (Gunawardena and Jayawardena, 2001; Praveen *et al.*, 2011) have indicated the necessity for immediate solutions. As one of the prominent solutions the factory based construction could be identified and its applicability to the Sri Lankan construction industry needs to be determined. The applicability may depend on many factors which are inherent to the factory based or offsite productions. There are benefits as well as the drawbacks of these systems. As construction projects are unique from one to another the benefits or draw backs may address the project in different ways. Therefore the pros and cons of off-site production over the in-situ products should be analysed very carefully.

In order to take an idea of level of usage of factory based products in Sri Lanka, in an environment where the established knowledge is less with regard to factory production, the needs to look at the international construction industry to form a firm basis to proceed. Therefore this research is aimed at identifying the nature of skill shortages in Sri Lanka and benefits over in-situ constructions that could be adopted and identify drawbacks that should be minimized. The knowledge published on other countries are analysed in order get a basic and to identify the potentials for expanding the factory based production in Sri Lanka.

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2. THE SKILLED LABOURER

According to Wikipedia (2012) a skilled labourer is any worker who has some special skill, knowledge, or (usually acquired) ability in their work. That particular worker may have gained his knowledge or skill from a college, university or technical school or gained it from his experience. In construction industry a worker can achieve skills on various fields such as masonry, carpentry and finishing.

3. SKILL SHORTAGE IN SRI LANKA

With the end of thirty years of civil war, the Sri Lankan Construction Industry has begun to expand rapidly to all areas as never before and is experiencing increased investment on infrastructure and high-rise and medium scale buildings (Praveen *et al.*, 2011). However, despite of this boom in construction, still it heavily depends on its labour force (Gunawardena and Jayawardena, 2001). The studies done on challenges faced by construction industry have shown that skill drain and shortage as a significant problem in the Sri Lankan construction industry (Rajakaruna *et al.*, 2012). Therefore it's clear that this problem is becoming worse and cannot be easily neglected.

Meeting the client's requirements of cost, time and quality of the work heavily relies on the performance of skilled labour and their acquired training and skills. The level of skill and updated knowledge about recently introduced techniques and technology are also important matters to be considered along with the adequacy of skilled labour. Ineffective manpower training and introducing to the construction labour force in both numbers and requisite skills can present continuing problems not only for the contractors but also for other stakeholders of the industry (Gunawardena and Jayawardena, 2001).

Further, Gunawardena and Jayawardena (2001) stated that the ongoing training programmes are supplying insufficient number of workers in comparison to the anticipated growth in the construction jobs, annually. Very low percentage of the workers at the craftsmen level categories in the Sri Lankan construction industry has undergone formal training similar to the countries Kenya (Njeri, 2008). Therefore the short supply of skilled labour is a key issue which need to be analysed and better solutions should be identified.

Razak (2012) also reported that there is a prevailing skilled labour shortage in craft person level and middle level technicians caused by the insufficient investment of training. Razak (2012) further reported that this may affect to the ongoing development processes if preventive measures are not taken immediately and that will hit on national economy severely.

Ratnayake (2013) stated that construction industry as a labour intensive industry as it employs a large work force. Numerous workers are engaged in construction industry all over the world, informally and their common intention is to earn a reasonable income, formal training, and recognition and retain in the sector until they are strong enough to involve in hard works. However Ratnayake (2013) concluded that very few percentage of workers retained in the industry after they reached 45 years of age and have experience higher than 10 years, unfortunately. Hence the industry is running with a risk of having a large unskilled workforce creating a skilled labour vacuum in the industry which should be addressed thoroughly. Therefore it's obvious that means of training skilled labourers should be promoted while necessary steps are taken to retain the valuable experienced skilled labourers within the industry.

4. AVAILABLE SOLUTION TO SKILL SHORTAGE

In the study done by Praveen *et al*. (2011), it was identified that the skill shortage can be minimized by increasing the intake to the training institutions, developing the existing training institutions and establishing new centres to yield a sufficient supply of skilled labour, motivation of new entrants to the skilled labour market and to sustain the existing skilled labourers by an acceptable attractive minimum salary scale for skills, introducing productivity based payment systems and recruiting minimum number of permanent or long-term contract based workers may encourage the employers to provide necessary trainings to the their workers. However Ratnayake (2013) in his research recommended a different option of factory based a construction which is less popular in Sri Lankan construction industry as one of the solutions to the skilled labour shortage in Sri Lanka. Further, Ratnayake (2013) stated the necessity for further research on the applicability of factory-based construction for the Sri Lankan construction industry which is the basis for this research. Although Praveen *et al.* (2011) determined those ways of minimizing the skill shortage, the option stated in Ratnayake (2013) requires less effort and less additional cost of implementation.

5. IN-SITU PRODUCTS AND FACTORY MADE PRODUCTS

According to Chudley (2005) and Friedman (1992) there can be two types of approaches to construction of buildings. They are *conventional method* and *industrialized method* which is also called as the off-site construction. The traditional methods are simple and more labour intensive and according to Chudley (2005) as it was taught to most of construction apprentices as a basis to enter the construction industry. The conventional type of construction is casted on site or stick built. That means construction products are produced at its permanent place. These are built from basic materials at the location (e.g.: brick walls, in-situ concrete slabs). However in the industrialized methods which are more advanced and complex are generally attached with mechanized processes. Chudley (2005) further argued that the conventional type is better to use in small construction projects and industrialized approach is for projects where there is a need of large number of units on a same site. On the other hand Chudley (2005) stated that industrialized methods are rationalized and are used to produce complete elements such as floors, walls and roof frames.

As defined by Stephan and Christopher (2010, p.485) factory made products are,

> "Building components that are constructed at a location where usually in a factory, remote from the building site. Off-site production is another term widely used to describe the manufacture of a prefabricated building. The Manufactured building or building parts are then delivered to the site and assembled in their final position."

Generally factory made products have the potential to improve productivity of the project. When using factory made products, the project duration may reduce and as a result of this, labour cost might also reduce. Other than that it can streamline the supply chain as cited in Haas *et al.* (2000).The builders are utilizing the factory made products in several forms. They can be identified as *modularized units, prefabricated units* and *preassembled units.*

Modularized units are factory-built units completely assembled or fabricated in a manufacturing plant away from the work site. After the fabrication, these are transported and assembled on site. The modules are large in size and possibly may need to be broken down into several smaller pieces for transportation. Buildings formed from modular units normally consist of multi-rooms with three-dimensional units, which are constructed and pre-assembled complete with trim work and services installed (Haas *et al*., 2000). Although Chudley (2005) argued factory based construction are suitable for small type of construction the above statements determines that factory based products can be used for large scale projects also.

Generally, as Haas *et al*. (2000) defined prefabrication term is used for one skill or trade, such as electrical, piping, or rebar. As Tatum (as cited by Haas *et al*., 2000) defined this type of product as a component produced at a specialized facility, in which various materials are jointed to form a component part of a final installation. The components that are manufactured offsite and do not form a complete system are considered to be prefabricated and these prefabricated components often only take part in a work of a single craft.

Preassemble units refers to components that are comprised with various types of building materials, prefabricated components, and equipment joined each other at a remote location for subsequent installation. It is generally focused on a system, rather than a product according to Tatum (as stated by

Lu and Bausman, 2009). (e.g.: roof trusses, platforms, piping, and ladders)

However according Lu and Bausman (2009) there are four types of factory products that can be used in building construction. In this study by Lu and Bausman (2009) it is stated that hybrid systems which are prefabricated a fully factory finished building facilities with completed internal furnishes and building services (e.g.: bathrooms and office spaces), panelized building systems which consist of the construction of the structural frame, or building envelop, using building panels manufactured in a factory. Further, the Constructing Excellence Ltd. web (2012) states that off-site production and uniqueness in construction are not incompatible and also the use of standard products does not limit the scope for design innovations. On the other hand, it's clear that in above researches it's tried to classify the factory based construction according to its degree of factory based production. From the small piece of element to total construction it varies.

Precast, pre stressed concrete structural elements which are often heard in building construction are crisp, slender in relation to span, precise, repetitive (Allen and Iano, 2009). They can offer economical framing for many kinds of buildings by combining the rapid all-weather erection of structural steel framing with the self-reproving of site cast concrete framing to offer economical framing. Since precast concrete is the newest and least developed of the major framing materials for buildings, its architectural aesthetic is still maturing according to Allen and Iano (2009). Allen and Iano (2009) further stated solid and hollow-core are ideal both functionally and economically, hence they have become an accepted part of structural vocabulary in schools, hotels, apartment buildings, and hospitals. Precast concrete has gifted the relaxation to Engineers and Architects of using that technology in longer-span building types, especially warehouses, industrial plants, and parking structures where its unique structural potential and efficient serial production of identical elements can be fully utilized and openly expressed. It can be identified that achieving highest architectural quality both inside and outside of buildings that consist of precast concrete, becoming increasingly successful. Therefore, Allen and Iano (2009) forecasted that it is reasonable to think that many innovative buildings in the coming years will be built of this sleek, strong, rapidly developing new technology. Since, factory based products related to other trades shall also be promoted using the pre-cast concrete as an example.

6. INDUSTRIALIZATION AND FACTORY PRODUCTION

According to Kumar *et al.* (2011), Industrialization means "industrial method employed with reference to mechanization, standardization and prefabrication". Warszawski (1999) stated that industrialization process is used for maximizing production output, improving quality and minimizing labour resources by investment in equipment, facilities and the technology to produce the elements inside a factory premises instead of directly on site. Industrialized construction is a process of standardization of the work processes in the industry to reach cost efficiency, higher productivity and quality and focusing on mass production and mainly factory production where work is centrally organizedas cited by Grimscheid and Scheublin (2010). Further it supports to produce a high quality, custom built environment, through an integrated process, optimizing standardization, organization, cost, value, mechanization and automation (Grimscheid and Scheublin, 2010). Introduction of Industrialized Building System (IBS) is one of the successive efforts towards construction industrialization. Warszawski (1999) defined the system building as a set of inter connected elements that are joined together and characterized it as a set of interrelated elements that act together to enable designated performance of building. Industrialisation in combination with transport improvement has earned the potential of avoiding from declining of local sources of building materials, since manufactured building materials have become available almost everywhere, allowing a wide choice of construction options for the clients.

7. ADVANTAGES AND DISADVANTAGES OF IN-SITU AND FACTORY MADE PRODUCTS

Haas *et al*. (2000) identified that if local labour for onsite work may be very expensive or inefficient, overall cost for a project that uses offsite work can be less than a traditional on site work. Severe onsite conditions and adverse weather conditions can lead to costly delays that can be avoided through off site work. Weather is a not an effective factor in prefabrication or modularization of construction products. In a controlled environment where direct effect of sunlight and harsh weather cannot effect the works are not delayed and quality is high (Baba *et al.*, 2012). Work is not interrupted and productivity can remain at a high level. Further, site congestion and interference can be avoided which increases the productivity and lowering unnecessary costs. The onsite construction duration can be substantially shortened through the use of factory products. More work for a project can be completed inside the factory, therefore the construction schedule is decreased. This is very important factor for owners who are in a hurry to take the return from their investment immediately. The safety of site can be improved through the use of offsite work and the risk to owners and contractors of worker accidents and lost time thereof can be minimized with construction work that is transferred away from the site (Haas *et al*., 2000).Further onsite work can be less safe due to ever changing conditions, elevated work, and congestion. On the other hand the quality of the work can also be improved due to the usage of controlled factory and production conditions and repetitive procedures and activities, along with automated machinery or robotics. A positive side effect of using factory products is the ability to decrease the environmental impact of the project due to reduced jobsite construction duration. There is generally a constant, employed workforce for offsite pre fabrication plants. Therefore simultaneous production or parallel work is possible within the factories. Since construction activities can be broken down and completed simultaneously at multiple locations instead of performing tasks in a strictly linear sequence onsite. This is also minimizing the length of construction duration and reduces onsite congestion (Haas *et al.*, 2011).

Further, Constructing Excellence Ltd. web (2004) states that due to the offsite work the maintainability and the replacements become easy. The standardization of building elements which will use the components, manufacturing methods or processes extensively, may increase the productivity due to the repetition.

It's noteworthy that, Manalo (2013) specifically commented on recycled pre-fabricated wall panels in his research made of rigid polyurethane foam and Magnesium Oxide board. Other than the common advantages of off-site production of environmental friendship (renewable resource, recyclable, and biodegradable) and lower cost these systems bear benefits of less energy consumption, light weight, and good specific mechanical properties. Manalo (2013) further commented on these systems of their numerous potential advantages in prefabricated housing construction such as better quality control, improved health and safety of workers, and less duration for construction. Prefabricated housing systems are easy, fast and economical to install as it requires minimal handling and reduces energy in the transportation (Hossain, 2000)

Haas *et al.* (2000) further stated the off-site production of building components can provide better precision in assembly, shorter construction periods due to simultaneous work, better value, and greater predictability. By producing in a controlled environment, it is possible to improve the safety of manufacturing, reduce waste and promote recycling, and lessen the damage to elements that can happen within site. However it should be understood that these benefits are in a tradeoff with its disadvantages. Although the controlled environments are supported by the ergonomically designed equipment, it leads greatly labourers with little room for skill advancement or intellectual challenge.

Another benefit that are being provided by factory product is creation of job opportunities away from the site which can diminish the problem of local labour shortage. Further, less number of workmen may need to be transported to the site which in turn can reduce the transport cost although material transportation cost is considerable issue of factory made products (Taylor, 2009).

When the notion of Manalo (2013) is considered despite its many advantages, the practice of prefabricated composite walls is low due to lack of standards and design. Currently, there is very little knowledge on the design and construction methods using new composite materials, performance and behaviour of this construction system under imposed loads. Singleton and Hutchinson (2009) indicated that due to the shortage of appropriate design guidelines, most factory based systems have noticeably failed to meet expectations by the owners.

One of the major disadvantage of the off –site production is the transportation according to Haas *et al.* (2000), because of the large and heavy sections need transported to the site from the factory premises some times over a long distances. Therefore this affects to the project cost highly and the duration may be affected due to inability to transport the factory made elements on time. Therefore Haas *et al.* (2000) further stated that the utilization of factory made products must be followed by the extensive design and planning. An interference analysis must be conducted in the planning stage to identify the handling difficulties at site, as the factory products are less flexible in handling and possibility of doing changes may not be easy after the manufacturing process starts.

Smith (2010) argued that usage of factory products are not an all-round solution that promisingly lower costs and higher quality. While greater reliance on manufactured production has created a bland, monotonous landscape, the cost and quality of buildingdoes not wholly depends on its method of fabrication. Smith (2010) further argued although factory productions reduce material waste, and it does not imply that the materials used in off-site construction are environmental friendly. Similarly, although it is said that buildings that may be disassembled as easily as they were assembled and reused and therefore the environment is preserved, these have limited to concept level that have not been addressed satisfactorily in the construction industry.

Therefore it's clear that factory based construction has its own advantages and disadvantages as discussed above. Since it's obvious, these have to be considered very well according to the scenario before determining up to what degree a particular construction shall be comprised with factory based products. The designer should be well aware of this situation.

8. APPLICATION OF FACTORY BASED PRODUCTS IN CONSTRUCTION INDUSTRY

Constructing Excellence Ltd. web (2004) has cited that it is necessary to have some awareness on the opportunities of using factory based products from the project inception, through the concept design and scheme design stages. It is said that there is a less use of investigating new opportunities after the scheme design phase. Further it says that in order to achieve full benefits client and contractor should have think of the factors such as standard frameworks or conventions for geometric fit, standard forms of construction process or methods, standard building elements, project standards and preassembled components or modules and the decision to whether on or off-site preassembly, from early planning phases of construction.

However, Griffith (as stated by Manalo, 2013) indicated that failing to understand the latest technology and the behaviour of innovative materials are the causes to inadequate performance of prefabricated building components which in turn causes in rejection. In addition, there is also no or less standards to guide the performance requirements regarding strength and serviceability for prefabricated composite wall systems in many countries. As there are very less number of scientific research have been undertaken to support the benefit of using new composite materials in prefabricated systems of construction most engineers continue to rely upon experimental test data while evaluating the structural performance of factory based products according to Toro *et al.,* (2007).

It has been very difficult to use the factory based construction due to above constraints, although it is said to use from the inception (Constructing Excellence Ltd., 2004). On the other hand without published standards and knowledge it's hard to evaluate the factory based products. Therefore the application of factory based products has been limited.

Although above problems were raised regarding the factory based construction products, the pre-cast concrete elements seems to be familiarized within the construction industry. According to Allen and Iano (2009), higher-strength, reuse of steel forms for hundreds of times, reducing waste, efficient usage of raw materials due to controlled environment, less sand use in finishing, ability to use optimized designs, ability to use high-quality architectural finishes which reduces the need for volatile organic compound emitting paints or other finish coatings, ability to withstand damages by moisture and prevention of mould growth, ability to create properly sealed joints in wall panels which can lower permeability to air leakage, ability to reduce building heating and cooling costs and contributing to good indoor air quality and its reusability made concrete elements more popular.

However, it is necessary to note that off-site production is not a sole solution to use across the whole of the industry or for a project totally according to Constructing Excellence Ltd. web (2004). According to the nature and the size of the project and its construction elements, the appropriateness of the preassembly or prefabrication is determined. It should be kept in mind that off-site production takes more time and effort to be applied at the beginning of a project although they can help ensuring higher quality standards and reduced on site construction time (Constructing Excellence, 2004).

9. USAGE OF FACTORY PRODUCTS IN PRESENT CONSTRUCTION INDUSTRY

The findings of Lu and Bausman (2009) indicated that “offsite construction techniques are incorporated into 23% of new building construction, in 2006 in the US construction industry”. The use of offsite construction techniques was restricted only within offsite preassembly techniques, such as precast concrete products and preassembled trusses although it is highly developed region (Lu and Bausman, 2009). Contradictorily, “the use of prefabrication and preassembly in US is estimated to have almost increased by 86% within the last 15 years”, according to Haas *et al.*, (2000).Further, the three main driving factors of the prefabrication and preassembly usage in US were schedule, workforce issues, and economic factors (Haas *et al.,* 2000).

Taylor (2009) stated that “value of off-site construction of buildings, building elements and structures is around 2- 3 billion Euro per year and accounts for around 2% of the total construction market.This had been a market share increase by 25% per year in construction industry in Europe”. Further it should be noted that volumetric or modular constructions have been popularized in North America, Scandinavia, and Japan according to Stephan and Christopher (2006).

All these researches have emphasized an upward trend in usage of factory based products. However underneath that change, a lower level of current usage is highlighted. Since it is clear, although statistics says about an upward trend, the factory based products have not been sufficiently promoted among construction industry at the moment. At the same time in countries like Sri Lanka there are no evidence for ascertaining the degree of using factory based products in construction industry.

10. CONCLUSION AND RECOMMENDATIONS

The construction industry is always challenging. Therefore it is essential to be always updated regarding new developments which can afford functional and economical solutions to prevailing issues in the industry. Although off-site production is not a new concept to the construction industry, its modern advancements has made a way for improving the construction productivity, reducing durations and wastages which in turn reduce the unnecessary costs which helps to keep a reasonable profit margin in a highly competitive market. In case of Sri Lankan construction industry, independency from the weather and other outdoor effects has been the best advantage, which over few years had experienced very unpredictable conditions.

The crucial benefit of the off-site production is its potential to provide solutions to skill worker shortage which most of the researchers have foreseen. With the industrialization of the manufacturing of building components the on-site work is reduced and less number of skilled workers are required in forming the building components within the factory supported by the automation activities.

According to many previous researches the quality of the factory made products are very high as they are formed in controlled environments where the harsh or the adverse weather not affecting factor. Similarly this will also help to reduce the duration as parallel works are possible within the factories.

However they do have their own draw backs as well. Therefore it is clear that the decision for using factory based products depends on many factors including preference of the client on the inherent benefits and nature and size of the project. This may be a cause for many writers to see the factory based products as not a sole solution for the construction industry or totally for a project. On the other hand one can raise a question that, if factory products can reduce the cost, why are they still not matured in developing countries like Sri Lanka where the people are always searching for the less cost solutions. However, still these problems are unresolved because of the inadequate knowledge on material prices of offsite products.

Although it is not clear to what extent the factory based products are used in Sri Lankan construction industry at present, other countries shows a provision to use of factory made components. The literature finding has justified the need to identify the labour intensive trades in the Sri Lankan construction industry to adopt factory based construction concepts.

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PSYCHOLOGICAL CONTRACT WITH CONSTRUCTION LABOUR FOR SUSTAINABILITY IN CONSTRUCTION

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ABSTRACT

The Construction Industry in general and its workforce in particular are the essential partners for rapid economic progress of a country. In the process of marching towards a developed nation, Sri Lankan construction industry has to play its due role. However, industry faces tremendous challenges to sustain the existing workforce and to attract additional skilled and unskilled workforce to the industry to deliver its promises. Effective Human Resource Management (HRM) practices to increase industry productivity standards and retention of construction labor through appropriate contracts with them were highlighted in this regard. Employment 'contract' is defined as the bond between the employer and employee for a given task. The emphasis of 'psychological contract' is to bring the importance of mutual trust and understanding between two parties where implied terms are vital than written contract.

This paper introduces a framework for Psychological contract with labour based on literature review and pilot interviews. Psychological contract model for construction labor contracts was proposed by emphasizing the 'remuneration and welfare', 'dignity' and 'motivation and performance of labour' as three main pillars for building the proposed model. Preliminary findings suggest adopting innovative HRM practices embedded with psychological contract for construction industry to ensure its sustainability.

Keywords: *Construction HR and Psychological Contract; Construction Industry Sustainability; Construction Labour Productivity and Motivation; Construction Labour Shortage.*

1. INTRODUCTION

Construction industry is ranked as the fourth highest sector contributing significantly to the economic growth of Sri Lanka. Shortage of skilled and unskilled labour and serious skill drain are critical issues in the Sri Lankan construction industry (De Silva *et al*., 2008). Thus, the importance of effective human resource management practices for the construction industry was highlighted (Weddikkara and Devapriya, 2000). Many developed countries have transferred their construction industry from labour-intensive to knowledge intensive industry. Sri Lankan construction industry is still a highly labour-intensive industry where, improving labour productivity is vital.

Applications on traditional human resource management (HRM) practices to recruit, retain, train and motivate construction labour is different and difficult when compared to other similar categories due to the unique project based nature of the construction industry. Initial literature review found the gap in research on HRM practices tailored into construction industry especially in Sri Lankan construction industry (Yankov and Kleiner, 2001; Senaratne and Hapuarachchi, 2009; Wijewickreme and Ekanayake, 2010; Weerasinghe and Ekanayake, 2013). It was a known fact that effective HRM practices could raise the construction industry performance by molding employee behavior (Brandenburg *et al*, 2006). It is vital to propose innovative HRM practices for construction industry to improve productivity with sustainable labour force.

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CONSTRUCTION INDUSTRY AND PSYCHOLOGICAL CONTRACT

In employment, 'Contract' is the foundation in employment relations, which sets up the basic in employer employee relationship in an organization. Rousseau (1990) defines 'Psychological Contract' is an individual's beliefs regarding mutual obligations. Beliefs become contractual when an individual employee considers that he/she owes his/her employer certain contributions as hard work, loyalty, sacrifices in return for certain inducements as high pay and job security. Hence, psychological contract will be operationalised with two sets of terms; employee-focused obligations which are to be fulfilled by the employee, and employer-focused obligations which are to be fulfilled by the organization. There are also two types of contracts such as transactional and relational contracts. Transactional contracts are mostly monetary exchanges and generally short term basis while relational contracts have both monetary and non-monetary exchanges as hard work and loyalty which are long term (Rousseau, 1990). In the case of contractual expectations, the promise of reciprocity or mutual obligations in exchange for some action or effort is the basis of the contract (Chandradasa & Ekanayake, 2011). Therefore, psychological contract is unique from other social exchanges which focus exclusively on inducements received in the mutual relationship.

Construction team is identified based on members' disciplines, interdependencies, team leader, accountability, consistency and objectives of them. Teams come from different disciplines have high interdependence in performance. Team leaders' role differs according to the contractual conditions (Senaratne and Hapuarachchi, 2009). Construction workers have less job security in general due to the project based nature of the industry. When there is job insecurity, the employees negatively act in their fulfillment of relational promises, but not to the same extent with the fulfillment of the transactional contract promises. In an organization, the employees exchange loyalty and their efforts for organizational benefits as salary, fringe benefits, working conditions (Shapiro, 2002). Based on the concept reciprocity, employees are motivated to get beneficial treatment by acting in ways that support the organization. Shapiro (2002) reveals that, trust lies at the heart of relationships and influences how each party behaves toward the other. In short term, the expectation of future benefits give positive behaviours towards organization; but in long term, if they were not fulfilled, it will lead to perceptions of contract breach and the undermining of trust which is crucial to the development of exchange relationships. The employees who have experienced violations of psychological contract may feel powerless to act against their employers' behavior and may simply adjust their own perceived obligations in order to remedy the situation (Robinson, Kraatz and Rousseau, 1994). Therefore, breaking a mutually agreed promise affects employee obligations much more than employer obligations and suggests considering subordinates' perceptions of mutual obligations as per the contract of employment. Hence construction companies to be careful about making promises and need to be aware that employees are different in accepting the norm of reciprocity in their exchange relationship.

Although the construction companies believe in the importance of human resource practices to the industry, there is a growing shortage of qualified workers and experienced managers and emphasized effective management of human resource (Yankov and Kleiner, 2001). Cox *et al*., (2005) suggested supervisors to look whether their subordinates motivated, satisfied, committed, and loyal in order to decide on the effectiveness of current management practices. If the workers are **motivated** they perform more work than expected, respond promptly to requests, correct problems, complete tasks at hand on schedule and plan own work. When the workers are **satisfied** they speak of company with positive regard, and speak of own job with positive regard. If they are **committed** they will remain with company in difficult times, ask about future projects, make sacrifices for well being of company, and speak of company with positive regard. And if workers are **loyal** they make sacrifices for well being of company, promote company and will abide by company policy.

MODELS FOR CONSTRUCTION LABOUR RETENSION

There are several models stating the importance of building mutual bond between employer and employee for retention of employees. Perceived Competency Mobilization model by Lai and Kapstad

(2009); Total Reward Model by Thompson (2002) and Ice Berg Model are the stepping stone to create Psycological contract model. Perceived Competency Mobilization model states that self efficacy, intrinsic motivation, perceived peer support, perceived supervisory support, salary system satisfaction and career opportunity satisfaction affect the effective skill utilization of employees. The successful implementation of this model will make the motivated and loyal employees remain in the organization. Ice Berg Model illustrates the concept of 'iceberg' to the Psychological Contract includes employee inputs and employer rewards below the water line of an iceberg. It is found that if ‘relational benefits’ are strong, the employee increases loyalty towards an employer, intention to stay, increase job satisfaction, trust and commitment. The factors ‘below the water-line’ are strongly a matter of how each other perceive on them unless brought out into the surface and clarified (Chandradasa & Ekanayake, 2011). Total Reward Model states components of good HRM practices for making a strong psychological contract. The model discusses two kinds of benefits. They are transactional which are more monetary based such as salary, wages and benefits. Relational benefits can be non-financial recognition as Employee of the month, organizational involvement opportunities for employees in its growth which makes them feel more valuable and organization needs its workers’ constructive contribution to achieve the organizational goals.

2. PSYCHOLOGICAL BOND BETWEEN CONSTRUCTION LABOUR AND THE INDUSTRY

Considering the findings of previous research on human resource management in construction industry, retention of labour is the major issue. According to the literature and interviewing industry experts and informal discussion with general construction labour helps to identify three main factors for psychological contract initial model development. Figure (1) shows the proposed psychological contract model that to help building a better mutual trust and understanding between employer and workers to reduce employee turnover.

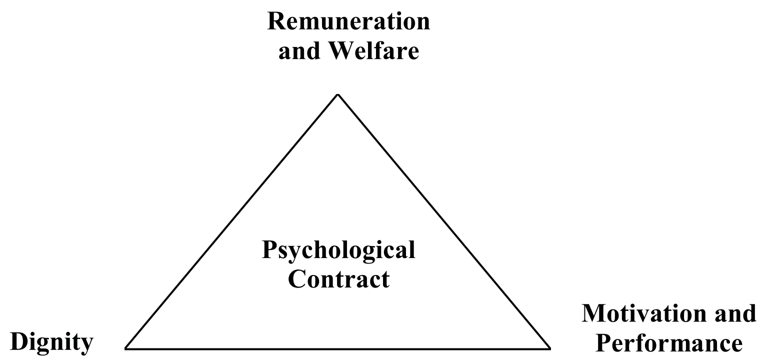

Figure 1: Psychological Contract Model (Chandradasa & Ekanayake, 2013)

2.1. DIGNITY OF LABOUR

Dignity of labour is that one’s respects for all others’ jobs and positions equally and does not consider one position is superior to another. A better way to increase the value of psychological contract at site without spending money is, employer and the superiors respect their subordinate and peer employees irrespective of their designation. Dignity of labour comprises with many factors. It was found that factors such as life balance options, recognition, better organization culture, effective leadership, good communication, opportunity of involvement in the job, ability to influence towards the ultimate goal, a sense of employees’ ownership and equity, perceived peer support, perceived supervisor support and, well-being and respect for the employees irrespective of their level of employment are important. According to Wijewickreme and Ekanayake, (2010), construction labour will not be a commodity anymore. They have to be treated as partners of the industry and society. As partners of any industry, they will become eligible to share profits.

However, literature revealed that most of the construction companies do not provide decent place for the workers' stay and to enjoy meals especially for construction sites labour. Even though it is believed that providing ownership and equity to workers in construction projects is difficult, the employer or superiors can get constructive ideas at occasional formal or informal meetings and discussions when moving on the project; or in daily problematic instances from workers in much more effective ways may be. Getting the ideas of these workers to succeed the project will make them delight as they feel they are important to the organization and they are valued among others. Construction companies should take steps to improve professionalism through enhancing professional practices, relationships and knowledge and the Codes of conduct and exposures could be helpful.

2.2. Remuneration and Welfare of Labour

The proposed model includes base pay, bonuses, long term incentives, pensions, salary system satisfaction, job security and, variety and flexibility and tolerance as components of remuneration. The workers who were not happy with their job tended to report more problems with the material, tools and consumables, and construction equipments than the workers with job satisfaction (Dai, Goodrum and Maloney, 2009). The companies should pay the workers on time as they are waiting for their stake at the end of the week or the month. Delaying the payments by two to three weeks had made the construction industry to have a bad image regarding the remuneration system and as a result youth does not like to join it. Poor welfare facilities for the workers too, have been identified by De Silve *et al*., (2008) as an area to focus on finding a mechanism to improve the existing conditions. Preliminary studies support remuneration and welfare of labour as one of the strong factor for building psychological contract. The best looking as at present is a 'Retirement Benefit' for construction labour (Wijewickreme and Ekanayake, 2010).

2.3. Motivation and Performance of Labour

The extent of construction accidents and social problems are much severe when compared to other industries and one main barrier to implement those standards and best strategies to minimize those lies with the low educational levels of construction workers (De Silva *et al*., 2008). The workers at construction industry are hired on project to project basis where the job security is missing. This 'project basis' nature of construction makes the workers employing for different contractors in the same time in different types of construction projects where they do not have loyalty towards a particular employer (Chandradasa & Ekanayake, 2011). Although the construction project cannot assure their workers' job security the organization can still adhere in to an industry acceptable standards in a way the loyalty towards the employer is enhanced.

Construction organizations cannot afford to make repetitive mistakes on major projects they should get the commitment of workers to perform better in moving ahead. On the other hand there are enormous benefits of repeating positive experiences from past projects. Carlos *et al*. (2009) suggest that effective lessons learned programme is a crucial element in the management of organizational knowledge because it will enhance the continuous improvement of processes and procedures and provide a direct benefit. The construction organizations can record the mistakes and positive aspects the company went through its life, analyse them and make implementation plans to enhance the quality of the current project; this is the basic idea of lessons learned programmes. Employers can do this using their own technologies and superiors should share them with workers at possible daily tasks. Further, maintaining a proper 'lessons learnt database' for every construction organization and organizations should also not rely heavily on individuals and the workers become motivated and will perform better at their jobs.

According to the elaborations by Chandradasa and Ekanayake (2011), the mutual understanding grows with the success and experience of the employee which increases the contract value and written contractual expectations on both sides. As per the illustrations above dignity, remuneration and welfare, motivation and performance are mainly contributing to the development of psychological contract of workers in the construction industry. It was identified that performance is the product of ability multiplied by the motivation *[Performance = 'Ability' X 'Motivation' (Effort)],* and ability is the product of aptitude multiplied by training and resources *[Ability = 'Aptitude' X 'Training' X 'Resources']* where, motivation is the product of desire and commitment *[Motivation = 'Desire' X 'Commitment']*. The five principle tools to overcome poor performance due to lack of ability is resupply, retrain, refit, reassignment, and release (Devid and Cameron, 2003). These factors which are yet to be proved with empirical research are used to build the psychological contracts where most of the contract phrases are unwritten and hidden. Motivating work environment is supposed to enhance satisfaction and that to be sustained with reinforcing performance enhancing behavior by using rewards and reinforces. Performance Development of the mutual understanding and trust of workers towards their employer and the industry using these three factors will make the employees build strong psychological contracts with their counterparts and thereby, the worker retention will be enhanced.

3. CONCLUSIONS

Human resource and human resource retention is a critical determinant of the survival of the construction industry. Everyone should build a strong consistency between management and employee needs through good human resource management practices. The construction teams are different from ideal teams due to lack of accountability and common objective and key issues related to teams are controlled by contractual conditions. Companies which balance employee welfare and company interest are more successful because the construction employment is not life time but project based. With an understanding of the issues of the construction industry in Sri Lanka, this paper reviewed the existing literature with an ongoing research project to develop psychological contract between employer and workers. It analysed three key factors to build psychological contract in the construction industry which to be proved with empirical research.

4. FUTURE WORK

Two separate questionnaire surveys being planned to collect necessary data from construction labours and construction professionals. Proposed psychological contract model may be modified if necessary after analysing the collected data. Model will be tested with interviews with selected labour and industry professionals.

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RELATIONALLY INTEGRATED VALUE NETWORKS FOR SUSTAINABLE PROCUREMENT

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ABSTRACT

Relationally integrated value networks (RIVANS) aim to boost collaboration in built infrastructure supply chains, thereby improving both efficiencies and value creation. However, in widely practiced traditional procurement modes, transactional forces are still complex and short-sighted, resulting in weak collaborative supply chain networks, while potentially beneficial relational forces remain untapped and/or fragmented, lacking well-defined common goals among stakeholders. RIVANS have been proposed to provide a holistic conceptual framework for relational integration towards the concept to all stakeholders in the built asset lifecycle, by engaging them in cross linked value networks. The ultimate goal is for sustainable procurement through RIVANS, by developing collaborating practices and overall value focus across the entire network and through the whole built asset life cycle. A questionnaire survey was carried out to elicit relevant opinions from industry professionals. The survey led to identifying eight potential synergies/better values by linking supply chains in Infrastructure Project Management (IPM) with Infrastructure Asset Management (IAM). Functional and relational integration were identified as an appropriate mechanism to achieving value through integration. The degree of importance of eleven common goals was identified in achieving 'better value'. The key stakeholders of D&C and O&M value networks were also identified.

Keywords: *Asset Management; Procurement; Project Management; Relationally Integrated Value Networks; Supply Chain Management.*

1. INTRODUCTION

Infrastructure Project Management (IPM) teams engaged in planning, design and construction up until the delivery of a built asset, often work independently from the Infrastructure Asset Management (IAM) teams which are responsible for its operation, maintenance, usage facilities and material recycling (Kumaraswamy *et al.*, 2004). Kumaraswamy *et al*. (2004) further highlighted, interaction and communication between these two teams are usually limited in the traditional procurement approaches where transactional force are very limited, resulting in weak collaborative supply chain networks. Therefore, managing client requirements becomes a complex process which is crucial to the successful delivery of construction projects. 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 systems (Yu *et al.*, 2013). However, with increased attention on customer satisfaction, sustainable buildings, life cycle cost, durable designs, designing and constructing for maintainability, interaction and working relationship between IPM and IAM has also become increasingly important. Thus, value networks with common values shared among project participants focus on optimising relational integration of project stakeholders through integrated processes that generate synergies, were

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identified as a better approach. These strengthen relational forces within client - led supply chain networks in IPM and IAM to achieve higher performance (Segerstedt *et al*., 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.*, 2010). 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 based on identifying common best value objectives of the entire stakeholders/network (including the client, consultants, contractors and suppliers in the supply chain), and 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. The basic concept of RIVANS is illustrated in Figure 1 (Anvuur *et al*., 2011).

The objective of the paper is to discuss potential efficiencies from RIVANS and improved practices that bridge the current divides between IPM and IAM.

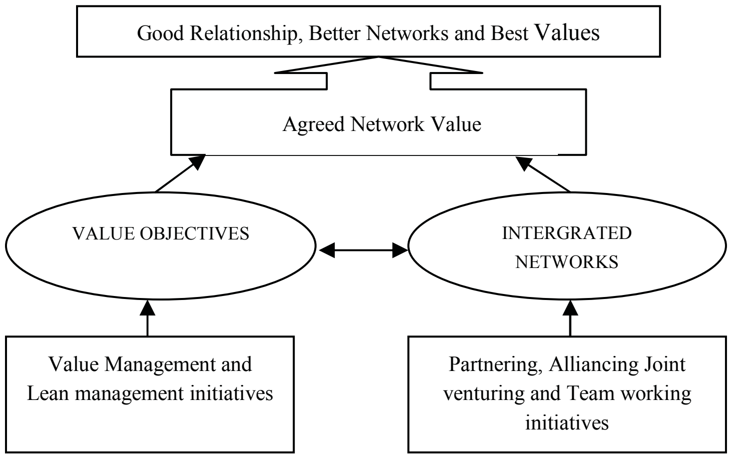

Figure 11: The Basic Concept of RIVANS (Anvuur *et al.,* 2011)

2. 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.

2.1. *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 organization, 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 minimized by selecting key persons from large projects and asset management organizations.

2.2. *QUESTIONNAIRE DESIGN AND QUESTIONNAIRE SURVEY*

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). 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 & C" and "O & M" value networks. Therefore, 11 of stakeholders were listed and respondents were asked to rank using the same five point Likert scale.

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.

3. RESULTS AND DISCUSSION

T-test, which is one of analysis procedures for Likert scale data, was used as a tool to establish potential better value/synergies, common goals and key stakeholders. Evaluation was carried out by using "Statistical Package for Social Science" (SPSS) software. To test the null hypothesis Ho: $\mu = \mu o$ against the alternative hypothesis H1: $\mu < \mu o$, where μo is the population mean. μo is the critical rating above which the issue was considered agreeable or ineffective. In this analysis, μo was fixed at 3 because, by definition, given in the rating scale, 3 is neutral.

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

Results showed that the appropriate integration activities/items between 'Design & Construction (D&C)' and 'Operation & Maintenance (O&M)', when appropriately mobilised, can be yielded better value/synergies by linking the usual supply chains in IPM with the usual supply chains in IAM. Eight better value/synergies were identified among the ten activities by the t-test (i.e. significance <0.05) (Table 1). Further, two activities/items such as similar procurement protocol and, overlapping supply chain networks were not significant.

Table 1 show all significant better value/synergies which are ranked according to their t-values. Further it shows their mean values and standard deviations to indicate the respondents' mean average and the deviation among the responses.

Table 1: Better Value/ Synergies by Linking the Usual Supply Chains in IPM with IAM

Better Value/Synergies	Mean	Std. Deviation	Sig (2 tailed)	t-value
1.Sharing relevant information	4.56	0.51	0.000	15.40
2.Addressing sustainability issue	4.44	0.51	0.000	14.21
3.Integrated business continuity management opportunities	3.92	0.49	0.000	9.32
4.Joint use of ICT tools (BIM -Building Information Modeling)	4.20	0.91	0.000	6.57
5.Integrated life cycle optimization options/opportunities	4.00	0.93	0.000	5.25
6. Integrated team building (Human Resource Capacity Improvements)	3.88	0.99	0.000	4.32
7.Arranging for some common /linked resource pool and requirements	3.72	1.06	0.002	3.39
8.Expanded long term business opportunities	3.75	1.15	0.004	3.19

Sharing Relevant Information

Results indicated that the sharing information and its communication is the most significant activity to yield better values/synergies. Sharing relevant information is very critical for the project management; uncertainty management and risk analysis have long been regarded as an internal project process to manage events that have an effect on the project's achievement of quality, budget and schedule requirements (Karlsen, 2010). Information can be practiced and thus prevent problems such as asymmetry and mistrust among the project stakeholders. Further, it can make node enterprises of supply chains to achieve order form strategy, construction capacity allocation, resource allocation and etc. (Zhang et al., 2012). The influence of information flow on supply chains is a long and dynamic process and its vital role related to functional coordination of project supply chains (Fox, 2009). Therefore, sharing relevant information flow enhances achieving the integration of project key stakeholders.

Addressing Sustainability Issue

Better value/synergies arise from addressing sustainability issue more effectively is a vital requirement as viewed by stakeholders. Sustainability has become an important issue in recent decades because it is a much more powerful rhetoric than simply being environment friendly. This is further underpinned by the development of methods, techniques and decision support tools that would facilitate sustainable appraisal and decision-making at the various project level interfaces (either from conceptualisation to design, construction, operation and decommissioning). As a whole, sustainability covers the entire project cycle of a project; sustainable infrastructure project is drive inception through delivery to life cycle use and finally disposal (Ugwu *et al*., 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).

Integrated Business Continuity Management

This is identified as the third significant activity for potential better values/synergies. 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). Thus integrated BCM initiatives typically focus on the continuous assessment of business needs, acceptable levels of risks in infrastructure projects to optimize operational availability. Further, BCM has reduced losses from the interaction of the equity, flexibility and alignment goals of management, workers and society (Low *et al*., 2010).

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 the 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). As per the questionnaire survey, the project organizations more perceive the ICT in grant. Currently, ICT is commonly used for many standalone applications for book keeping and two-dimensional drawings. 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).

Life Cycle Optimization Options/Opportunities

Results showed that the life cycle optimization is more dominant driver in infrastructure project to boost interaction and working relationship between IPM and IAM. Further designers have more knowledge of operational and maintenance issues and asset managers have better understanding of design intent and material equipment choices (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 *et al*., 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. The life cycle relationship between the design and construction and operation and maintenance of infrastructure project is driven by different factors such as environment and technology (Pelzeter, 2007). It drives comparing of actual and budgeted costs, which facilitate of better pricing decisions, improved profitability assessment, enhanced understanding of project environmental effects, and focusing on the costs incurred after construction or development (Korpi *et al*., 2008).

Integrated Team Building (Human Resource Capacity Improvements)

Results showed that integrated team building (ITB) is significant for potential better values/synergies of infrastructure projects. ITB balances three competing quality targets; equity, flexibility and alignment (Aghazadeh, 2003). The competing values over time is directed towards the continuous improvement and it depends on infrastructure project management and infrastructure project employees' ability of meeting customer's expectation (Langbert *et al*., 2002). Thus, ITB has reduced losses from the interaction of the equity, flexibility and alignment goals of management, workers and society. It has also helped to improve integrated values of infrastructure projects.

Common Linked Resource Pool

The common linked resource pool is yielded potential synergy by linking usual supply chains in IPM with IAM. 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 *et al*., 2012). Further, this ensures the maximum use of resources. Thus, IPM team and IAM team are encouraged to integrate to make use of resource pools. Ultimately, this grants and ensures smooth functionality between D&C and O&M stages.

Expanded Long Term Business Opportunities

Fueled by collaborative technologies that allow new ways of organizing and changing from a process-centric view of work to human-centric view of project due to its value creative networks (Alee, 2008). Thus impact of the long term business opportunities is likely to be significant and to generate shareholders' capital gains (Hughes *et al.,* 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).

3.2. ACHIEVING BETTER 'VALUE' THROUGH INTEGRATION

The appropriate types of integration of eight exploitable synergies between D&C and O&M identified through percentage calculation (Table 2). Five synergies were shown, functional integration as the best appropriate type whereas three synergies were shown relational integration as the appropriate integration. However, none of exploitable synergies were indicated transactional integration as the best approach.

Table 2: Achieving 'Value' through Integration

Better Value /Synergies	Functional	Relational	Transactional
1.Sharing relevant information between Design and Construction (D&C) and Operation and Maintenance (O&M) teams	**64%**	28%	8%
2.Joint use of ICT tools	**60**%	24%	16%

3. Integrated team building (Human Resource Capacity Building)	**56%**	32%	12%
4.Arranging common/linked resource pool ands and requirement	**48%**	28%	24%
5.Integrated "Business Continuity management"	**40%**	36%	24%
6. Expanded long term business opportunities	24%	**56%**	20%
7. To address sustainability issue	32%	**48%**	20%
8. 'Life cycle optimization' option/opportunities	36%	**44%**	20%

Functional Integration (Merging Functions)

Functional integration indicates merging functions (like 'design' and Construction' in D&B) under one organization and it tends to invoke positive connotations. Results showed that exploitable synergies between D&C and O&M 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. Functional integration implied consensus across functions and merged in to a single entity (Karlsson *et al.,* 2010).The achieved integration denoted that the highest significance of sharing relevant information between D&C and O&M. Further, functional integration can be granted with appropriate used of ICT tools such as BIM that can integrate stakeholders of infrastructure projects through sharing information. Integrated team building arranging common linked resource pool and requirement and integrated business continuity management can also be originated and improved functional integration as it automatically forms long term cross-networks with various stakeholders.

Relational Integration (Coorporative Relationship Built On Shared Goals)

Relational integration indicates organizations (e.g. in a supply chain) collaborating well through corporative relationship built on shared goals and values. When project participants are engaged in cross-linked value networks, with overall common values shared among project participants focus on relational integration of project teams through integrated process that generate synergies (Kumaraswamy *et al*., 2010). This strengthens relational forces within client led supply chains in IPM to achieve higher performance. Relational integration is mechanism to manage resources shared among the organization (Anvuur *et al*, 2011). Results showed that the highest percentage against expanded long term business opportunities, address sustainability issue and life cycle options/opportunities are ranked under relational integration where basic trust on this research was empowering relational integration towards the sustainable procurement. Thus, it indicates that the network created through relational integrations is long-term and can utilize the entire life cycle of a project.

3.2.2. COMMON GOALS IN ACHIEVING 'BETTER VALUE'

Eleven common goals in achieving 'better value' through above synergies were identified and are listed in Table 3. "Relationally Integrated Value Networks" (RIVANS), based on identifying common goals of the entire team/networks (including the client, consultants, contractors and suppliers in the supply chains), and building better relationships - mostly by jointly focusing on, and working towards such common goals which were highlighted in achieving better values, in the literature (Kumaraswamy *et al*., 2010). In this research, common project goals such as cost, quality, time and safety were identified as most significant. Relationship building and management, efficient and effective communication, dispute minimization and management are also common goals in achieving better value. Further both life cycle oriented project outcomes (life cycle benefits and cost profiles) and life cycle oriented project drivers (overall sustainability concerns) were ranked as common goals. The efficient resource utilization and management, organization capacity building, long term network building, shared corporate social responsibility and expanded business opportunities are ranked as common goals. However, as highlighted in the literature, a relational network such as RIVANS can create a momentum in the construction industry.

Table 3: Degree of Importance of Common Goals in Achieving 'Better Value'

Common Goals	**Mean**	**Std. Deviation**	**Sig (2 tailed)**	**t - Value**
1.Common project goals such as cost, quality, time, safety	4.76	0.52	0.000	16.83
2. Relationship building and management	4.16	0.37	0.000	15.50
3.Effective and efficient communication	4.6	0.58	0.000	13.86
4. Dispute minimization , management & resolution	4.24	0.66	0.000	9.35
5. Lifecycle oriented project outcomes , including life cycle benefit-cost profiles	4.12	0.67	0.000	8.41
6. Lifecycle oriented project drivers , including overall sustainability concerns	4.36	0.81	0.000	8.39
7. Efficient resource utilization & management	4.32	0.85	0.000	7.74
8.Organizational capacity building	4.04	0.81	0.000	6.33
9.Long term network building	3.96	0.81	0.000	5.82
10.Shared corporate social responsibility	4.04	1.02	0.000	5.10
11. Expanded business opportunities	3.52	0.71	0.000	3.64

3.3. KEY STAKEHOLDERS OF "D&C' AND "O&M' VALUE NETWORKS

The importance of key stakeholders for delivering 'better value' by mobilizing /exploiting 'synergies' between D&C and O&M supply chains are shown in Table 4. Twelve key stakeholders of 'D&C' value networks are identified through the t-test and ten key stakeholders of 'O&M' value networks are identified through the t-test. Stakeholders have varying levels of responsibility and authority when participating in a project and these can change over the course of the project's life cycle, occasional of contributions (Othman, 2011). Thus, according to their varying levels of responsibility and authority, results showed that client is the most important key stakeholder during IPM whereas second important stakeholder during IAM. This may be due to lack of integration between IPM and IAM phases of projects. However, the client has a greater responsibility for engaging stakeholders in framing of individual service specification (Heywood, 2006). Main contractor is second key stakeholder during IPM. Design and principal consultant, relevant salutatory bodies, project financiers, relevant governmental organization, and (principal/sub) consultants are identified as important. Further, sub-contractors and users are key stakeholders in IPM and they have similar weights. The relevant non-governmental organization, suppliers and general public are also key stakeholders in IPM and they have less weight compared to other stakeholders in IPM. This may be due to their lesser authority in project management. Further, results showed that the relevant governmental organization is most important key stakeholders, followed by the client, in IAM among ten identified stakeholders. Respondents may believe that relevant governmental organization is the most important as almost of the infrastructure projects such as highways owned by the local government and has more enforcing powers. Users are the third key stakeholders in IAM. The values of infrastructure projects in IAM phase is gained by users ultimately. The smooth functionality of infrastructure projects is lead to grant benefits to the owners. Relevant statutory bodies, general public, project financiers, designers and principle consultant, (specialist/sub) consultant and main contactors are highlighted as important key stakeholders in IAM.

Table 4: Key Stakeholders of 'D&C' and 'O&M' Value Networks

Stakeholders	Design & Construction				Operation & Maintenance			
	Mean	Std. Deviation	Sig (2 Tailed)	t Value	Mean	Std. Deviation	Sig (2 Tailed)	t Value
1.Client/Owner	4.84	0.37	0.000	24.58	4.04	0.84	0.000	6.19
2.Main Contractor	4.60	0.76	0.000	10.47	3.68	0.99	0.000	3.44
3. Designer and Principle Consultant	4.48	0.71	0.000	10.36	3.92	0.95	0.000	4.82
4. Relevant Statutory Bodies	4.24	0.72	0.000	8.57	4.04	0.95	0.000	5.35
5. Project Financiers	4.28	0.94	0.000	6.84	4.16	1.14	0.000	5.07
6. Relevant Governmental Organizations	4.16	0.85	0.000	6.82	4.36	0.91	0.000	7.49
7. (Specialist/Sub) Consultant	3.96	0.79	0.000	6.08	3.88	1.09	0.000	4.03
8. Sub-Contractor	4.16	1.02	0.000	5.64				
9. Users	4.16	1.03	0.000	5.64	3.96	0.84	0.000	5.71
10.Relevent Non-Governmental Organization	3.84	0.76	0.000	5.63	3.92	0.93	0.000	4.84
11. Suppliers	3.88	0.88	0.000	4.99				
12.General Public	4.00	1.19	0.000	4.47	4.04	1.00	0.000	5.11

4. CONCLUSIONS

The findings was identified that there is shortfall traced to persisting disconnect between 'design and construction' (project management phase) and operation and maintenance (asset management phase). Further, this research has shown innovative signs for the potential application of RIVANS, which focused on developing corporative/collaborative relationship in the pursuit of overall value. The significance of eight better values/ synergies by linking the usual supply chains in IPM with usual supply chains in IAM was identified. The better value/synergies were sharing relevant information, addressing sustainability issue, life cycle optimisation options/opportunities, common/linked resource pools, expanded long term business opportunities, integrated team building, joint use of ICT tools and integrated business continuity management. Further, the research found that the value through integration is basically shaped up with functional and relational integration. Functional integration indicates merging functions (like 'design' and Construction' in D&B) under one organization and it tends to invoke positive connotations. Thus, Relational Integration indicates organizations (e.g. in a supply chain) collaborating well through corporative relationship built on shared goals and values. The basic concept/trust of this research was relational integration based on identifying common best value objectives of the entire team/network (including the client, consultants, contractors and partners in the supply chain), and building better relationships - mostly by jointly focusing on, and working towards such common shared value. Therefore, the degree of importance of eleven common goals was identified. They are common project goals such as cost, quality, time and safety, relationship building and management, effective and efficient communication, dispute minimization, management and resolution, life cycle orientation, efficient resource utilization and management, organisational capacity building, long term network building, shared corporate social responsibility and expanded business opportunities. Twelve key stakeholders of IPM and ten key stakeholders of IAM as driving forces of RIVANS were also identified. Ultimately, RIVANS is conceptualised as a viable strategy for sustained competitive advantage.

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ROLE OF ACADEMIC RESEARCH IN SUSTAINABLE CONSTRUCTION PRACTICE

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ABSTRACT

Higher education is becoming a major driver of economic competitiveness in an increasingly knowledge-driven global economy. A university is a scholarly organism committed to inquiry, investigation and discovery at all levels with an embedded symbiotic relationship between teaching, research and practice. In addition to the primary duty of delivering good quality teaching, universities have another key responsibility: that is to add new knowledge to the wider society through research. Furthermore, the outcome of the research should serve educational needs and the development of the region and its economy.

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. Research and Development 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 sustainable construction practices arising from research and development activities. This paper argues that the research conducted by university academics in the built environment discipline should be directed towards this industry need of sustainable construction practices.

Within this context, the aim of the study is to address the role of academic research in sustainable construction practice. A comprehensive literature survey was conducted through referring to refereed published material in the related area. Study revealed that academic research can play a major role in developing sustainable practices in construction. The paper reports only the findings of the literature review. Field study will be done using case study approach to explore the actual situation in Sri Lankan context.

Keywords: *Academic Research; Construction Industry; Sustainable Construction Practices.*

1. INTRODUCTION

In recent practice, higher education is becoming a major driver of economic competitiveness in an increasingly knowledge-driven global economy. In addition to the primary duty of delivering good quality teaching, universities have another key responsibility to add new knowledge to the wider society through research. Researchers receive a number of benefits resulting from their research activity which accrue to the human, financial and intellectual resources of the university, and which subsequently benefit students, and ultimately the relevant industry. The construction industry is considered to be one of the most important industries in the economy. Today in a highly competitive world, construction organisations need to adapt continuously to complex and changing conditions, in order to survive and proliferate through innovation. However, the construction industry is having very unique nature of its own and is frequently complained as a slow moving industry. It is important for the construction industry to move beyond the traditional practices to adopt new practices arising from research and development activities. It is crucial that the academic research findings arising out of built environment related faculties should address construction industry R&D (Research and

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Development) requirements to make them useful for the industry. However, there is lack of evidence that construction industry adopts new findings of R&D activities into their practice. In fact, partnerships amongst governments, the economic sector and research universities are growing considerably, to make sure that new knowledge becomes linked to development goals. However, relationships between academia and industry are increasingly intimate and commercial. This urges the need of merging academic research and practice as the way forward to achieve a better responsive construction industry.

2. ROLE OF HIGHER EDUCATION INSTITUTES

A university is a scholarly organism committed to inquiry, investigation and discovery at all levels with an embedded symbiotic relationship between teaching and research (Boyer Commission, 1998). In that, universities have a significant role and a responsibility in shaping the culture, paradigms and practices of those professions (Fielden, 2008). During the last half of the twentieth century, a dramatic change took place in higher education. For example, Brezis and Crouzet (2004) state that the number of universities and colleges has raised, and the number of students increased even more. Quality driven initiatives are happening at the same time as universities are facing with continuing financial demands arising out of diminishing financial support from public sources of finance together with the high requirement of funds for developing activities.

Cullen (2003) has come-up with the set-up given in Figure 01 to enhance the quality of a university in a self funded basis while balancing several aspects of a university. The process starts with the learning and growth perspective, where the main focus is on enhancement of teaching and the academic research. This gradually should extend to internal customer and financial perspective as illustrated in the Figure 1. This setup is more applicable to a self funded system and not directly for a state funded system which is common to be seen in Sri Lankan context. However, state funded university even can gradually move to this model with some effort.

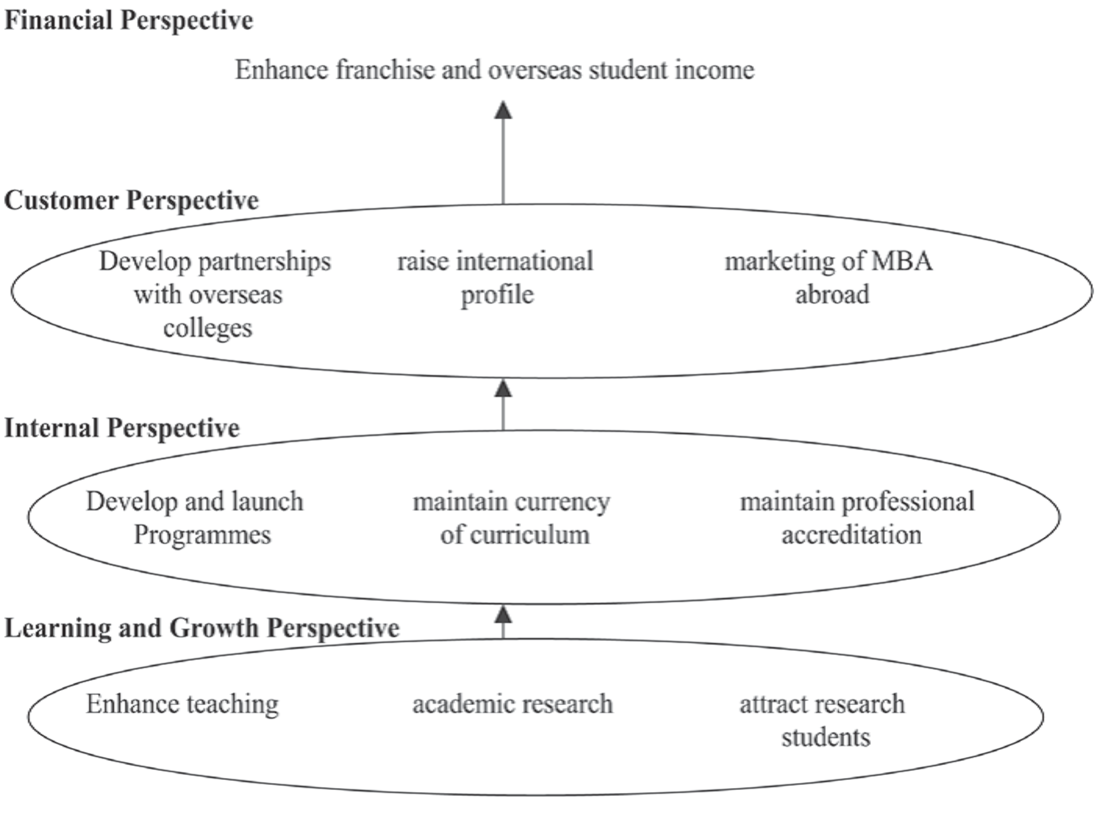

Figure 1: Strategy Map to Enhance University – Faculty Overall Quality
(Source: Cullen (2003)

Further, Figure 2 maps key parties interested in higher education and the perspectives from which they see the role of a today's university. Houston (2008) through this representation points to the complexity of the inter-linked environments and expectations in which universities operate. Interested parties see the university from economic perspectives (employers, industry groups), from societal perspectives (families of existing and potential students, community organizations) and from educational perspectives (academic disciplines, other education providers). Other interested parties bridge across these environments (for example, professional bodies bridging educational and economic perspectives), while yet others try to bridge multiple perspectives and positions. For publicly funded universities, the government as a key funder of higher education is a crucial stakeholder. Some external interested parties see the university primarily in local contexts, while others see it in national and international contexts.

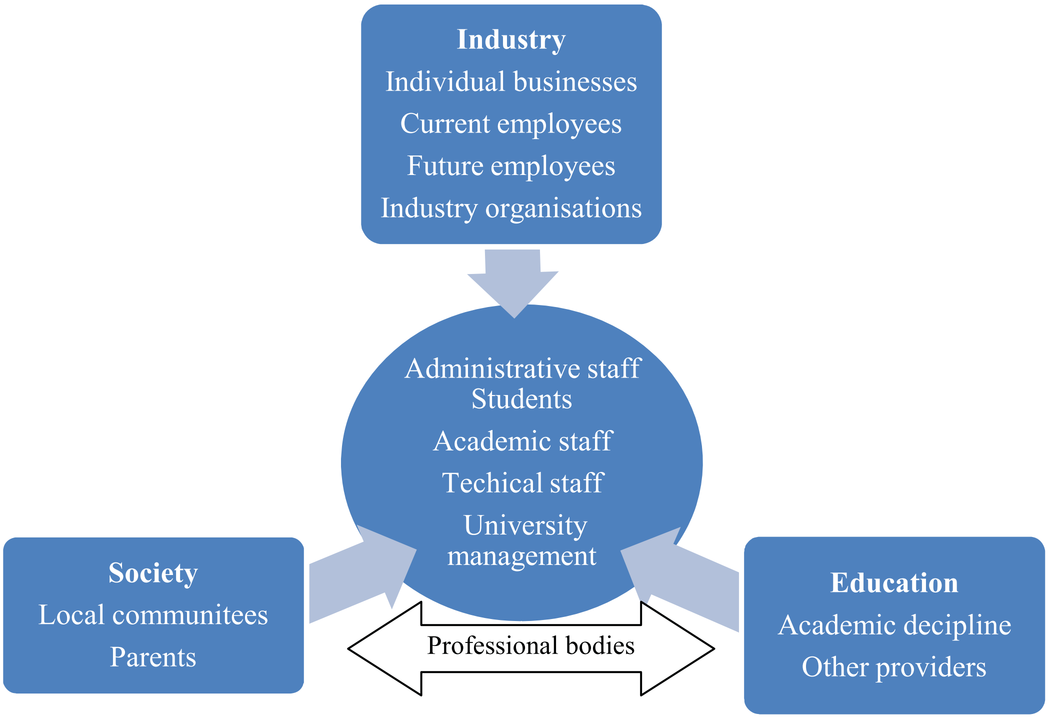

Figure 2: Location of a University at the Society
(Source: Houston, 2008)

In this model, Houston (2008), fairly represent the complexity of university within its environment. While the present day university needs to accommodate and respond to these key external parties (education, industry and society) and their expectations, they need to balance between the three aspects teaching, research and external engagement.

3. Role of Academics in Three Scholarships: Teaching, Research and External Engagement

Boyer's model of scholarship as in the 1990 publication "Scholarship Reconsidered" proposes that scholarship includes following categories:

- The scholarship of teaching and learning that is the systematic study of teaching and learning processes.
- The scholarship of discovery that includes original research that advances knowledge; and, the scholarship of integration that involves synthesis of information across disciplines and time

- The scholarship of application (also later called the scholarship of engagement) that goes beyond the service duties of a faculty member to those within or outside the University

The first scholarship is the teaching role of an academic while the next relates to the research role. The other scholarship describes the academic role beyond teaching and research to engagement with external parities such as industry and community.

Academic's main role is to teach the undergraduates and prepare them for their future professional duties. For instance, Centra (1993, p. 42), defines effective teaching as, "that which produces beneficial and purposeful student learning through the use of appropriate procedures" while Braskamp and Ory (1994, p. 40) include both teaching and learning in their definition, defining effective teaching as "creation of situations in which appropriate learning occurs; shaping those situations is what successful teachers have learned to do effectively". Though there are disagreements upon a 'one' particular definition it all suggest as a process of 'making students learned' on the areas that learners need to be a professionally capable personalities.

In addition to the primary duty of delivering good quality teaching universities' have other key responsibility is to add new knowledge to the wider society through research (Haughton *et al.*, 2003). Academics should carry out research that serves educational needs and the development of the region and its economy as part of the academic carrier. Research comes as an integral part of the carrier development of academia. Nonetheless, lecturers receive a number of benefits resulting from their research activity. Research is the orderly investigation of a subject matter for the purpose of adding to knowledge. Research can mean're-search' implying that the subject matter is already known but, for one reason or another, needs to be studied again. Alternatively, the expression can be used without a hyphen and in this case it typically means investigating a new problem or phenomenon (Postlethwaite, 2005).It has been identified that in scientific research, the tension between basic and applied research is the core issue, thus linking to the "think global, act local" challenge (Kassel, 2009). In fact, Virolainen (2007) argues that the research conducted in higher education should be more biased towards applied sciences compared to pure sciences. However, Barrett and Barrett (2003) holds the view that there should be conceptual research undertaken by researchers, as they will ultimately develop to be relevant and useful research outcomes for practice. In fact, such research though may not be immediately usable, will in the long run gradually penetrate to the industry. Hence, research be it applied or pure, accrue to the human, financial and intellectual resources of the university, which subsequently benefit students, and ultimately the relevant industry (Brown, 2005).

Apart from the above mentioned two scholarships of teaching and research, university academics have a third role to play – scholarship of engagement both as the processors of knowledge and the processors of fresh professionals to the industry (Boyer, 1990). While community engagement (service to the society) is becoming an important role of an academic, this research will mainly look into the industry engagement of an academic, done through disseminating academic research knowledge into the industry. Even though the line of communication is not direct as with the students, academics may follow number of channels to disseminate the knowledge to the already practising professionals to update their knowledge. Professionals in a particular industry altogether with the other related stakeholders are the hand which govern, lead and direct the industry towards development. Therefore they need to be updated with the changes happening in the global environment. With that the industry intellectual drivers would be able to avoid the knowledge base getting obsolete. Under this circumstance, the industry engagement of an academic through research knowledge dissemination could be identified as a major prospect for the development of sustainable practice of a particular industry.

Even though the three scholarships were discussed here separately, they are inter-related in actual scenario. Therefore the next section will describe such inter-relationships in order to explain the actual face of academic responsibility.

4. INTER-RELATIONS BETWEEN THE THREE SCHOLARSHIPS

The higher education systems in world as revealed in the previous section have significantly changed over the last decade resulting in mixed impacts on the research, teaching and external engagement. The strength of the link in between these three scholarships is problematic. The link is not only a matter of intellectual or disciplinary import, but is complicated by political and vested interests.

As per the Figure 3, three links could be identified. In looking into research and teaching relationship, the extreme points are clear enough. Research is an activity which is concerned primarily with knowledge acquisition on the part of the researcher, and secondarily with knowledge dissemination to academic peers and students. Teaching is an activity which is primarily concerned with knowledge dissemination on the part of the lecturer and with knowledge acquisition on the part of the student.

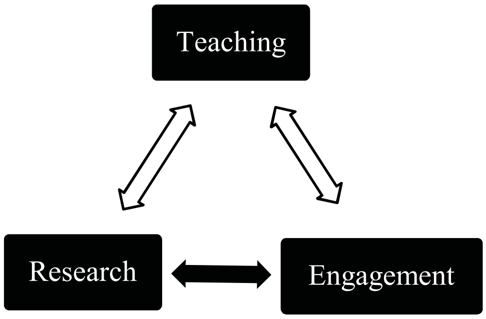

Figure 3: Interrelationship between Teaching, Research and Practice

The Boyer Commission Report on Educating Undergraduates in the Research University, a report from the US, found that the universities who consider themselves research-led are heavily involved in linking research and teaching. However, changes in quality assurance mechanisms and funding mechanisms have created negative impacts on the relationship between R&T (Research and Teaching) (Senaratne *et al.*, 2005). Further, Baker *et al.* (1998) discusses that as research is more rewarding compared to teaching, academics aim for research excellence at the expense of teaching excellence. This issue is not just unique to UK, but is an issue of international relevance. For example, the Boyer Commission on Educating Undergraduates in the Research University (1998) addresses this issue by calling for significant changes in undergraduate education in the USA; and, Brew (2003) explains similar issues in the Australian context. With such a background it is clear that there is a strong link between research and teaching. The link between teaching and industry engagement is again very clear in professional-oriented undergraduate programmes. In such programmes, teaching itself could be identified as a pathway of dissemination of academic knowledge to the industry practice.

It is the research to industry relationship that is focused in this study. This is explained in detail in the next section. On the whole, it is clear that the three areas, teaching, research and practice are having cohesive inter-relationships. However, when the three aspects are inter-linked, for example, when academics engage in research and transfer that research knowledge to students in their teaching activities and also disseminate that research knowledge to the industry, the three roles naturally takes place. Hence, it is the appropriate balance that academics should consider in their roles. The next part of this paper discusses the research and practice relationship in the context of construction industry with an ultimate aim of improving sustainable construction practice in the construction industry.

5. IMPORTANCE OF ACADEMIC RESEARCH TO IMPROVE SUSTAINABLE CONSTRUCTION PRACTICE

However at present, 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. Particularly challenging is ensuring that universities maintain their traditional role in public science while partnering with a commercial entity with a tradition of proprietary science (William, James, Graem and Surge, 2004). Furthermore, higher education should support individual professional development. It should also carry out research that serves educational needs and the development of the region and its economy (Virolainen, 2007). In this way, the researching will add more meaning in to the life of the industry which would lead ultimately for a better responsive construction sector.

In a highly competitive world at present, construction organisations need to adapt continuously to complex and changing conditions. Hence, lot of new trends are being introduced to the industry such as waste management, risk management, building information modelling, echo friendly technologies and so on to sustain the construction practice. Responding to these trends would create it is easy for the organisations to survive and proliferate through innovation. The internal dynamics of construction organisations must be such that they can respond to change by adapting their structure and orientation to reflect, and be able to respond to change (Steele and Murray, 2004). It is therefore important for the construction industry to move beyond the traditional practices to adopt new practices arising from research and development activities.

Therefore, the need for sharing knowledge between research institutions and industry has become increasingly evident in recent years. However, the past decade has seen a significant change in the roles of both parties as discussed before. Many companies are developing open innovation approaches to R&D, combining in-house and external resources, and aiming to maximize economic value from their intellectual property, even when it is not directly linked to their core business. In particular, they have begun to treat public research as a strategic resource. Further , European Commission (2007) states, it has become clear that research institutions need to play a more active role in their relationship with industry in order to maximize the use of the research results. This new role requires specialist staff to identify and manage knowledge resources with business potential, i.e. how best to take a new idea to market, ensure appropriate resources (funding, support services, etc.) to make it happen, and to obtain adequate buy-in by all stakeholders. In a study of Sparrow, Tarkowsky, Lancaster and Mooney, (2009), it has been identified that much of the research and practice of university-industry interaction is rooted in transfer of research expertise from universities to industry. Communicating research outcomes lies at the heart of academic endeavour, because it contributes to improved knowledge and understanding and guides further research. Moreover, the bigger the project and the higher the level of the degree, the more likely it is that research outcomes that 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).

At the present some developed countries have identified the importance of academic research in this endeavour. The Table 01 presents a collection of actions towards achieving sustainable construction practice. Factors were identified from strategic plans developed concerning different countries namely UK, New Zealand and India where the importance of academic research already acknowledged.

Table 1: Directions from Academic Research for Sustainable Construction Practice

Research Drivers for Construction Sustainability	Outcomes/Way forward
Strategy for Sustainable Construction (Flint, Pearson, Hodge, Jordan and Davies, 2008)	
Procurement	To achieve improved whole life value through the promotion of best practice construction procurement and supply side integration in both the public and private sectors and throughout the supply chain.
Design	The overall objective of good design is to ensure that buildings, infrastructure, public spaces and places are buildable, fit for purpose, resource efficient, sustainable, resilient, adaptable and attractive. Good design is synonymous with sustainable construction. Research can aim to achieve greater use of design quality assessment tools relevant to buildings, infrastructure, public spaces and

Research Drivers for Construction Sustainability	Outcomes/Way forward
	places.
Innovation	To enhance the industry's capacity to innovate and increase the sustainability of both the construction process and its resultant assets.
People	An increase in organisations committing to a planned approach to training (e.g. Skills Pledges; training plans; Investors in People or other business support tools; Continuous Professional Development (CPD); lifelong learning).
Better regulation	Reduction in the administrative burdens affecting the private and public sectors.
Climate change mitigation	Reducing total UK carbon dioxide (CO2) emissions by at least 60% on 1990 levels by 2050 and by at least 26% by 2020. Within this, Government has already set out its policy that new homes will be zero carbon from 2016, and an ambition that new schools, public sector non-domestic buildings and other non-domestic buildings will be zero carbon from 2016, 2018 and 2019 respectively.
Climate change adaptation	To develop a robust approach to adaptation to climate change, shared across Government.
Water	To assist with the Future Water vision to reduce per capita consumption of water in the home through cost effective measures, to an average of 130 litres per person per day by 2030, or possibly even 120 litres per person per day depending on new technological developments and innovation.
Research Drivers for Construction Sustainability	**Outcomes/Way forward**
Biodiversity	That the conservation and enhancement of biodiversity within and around construction sites is considered throughout all stages of a development.
Waste	Reduction of construction, demolition and excavation waste to landfill.
Materials	That the materials used in construction have the least environmental and social impact as is feasible both socially and economically.
The Research Strategy for the Building and Construction industry (Crisp, Burghout, Preston and Aitken, 2012)	
Better buildings	*Building envelope, Internal environments, Resilient buildings, Indoor air quality and moisture control, Better insulated and more airtight, the importance of understanding the role of ventilation, Perform more dependably in fire situations, including post earthquake fires.*
Materials performance	Improvements in the performance of traditional material, viability and applicability of new and innovative building materials, Best use of existing materials, Reuse of existing materials, Indigenous materials, Low environmental impact materials, Performance Assurance,
Maintaining and improving the performance of existing buildings	Retrofit solutions, Building condition
Sustainability	Measuring sustainability, What guidance, support and tools are needed in order to help industry to better understand and benefit from sustainability including benchmarking sector performance from a whole of life perspective, New technologies.
Automation, industrialisation and new technologies	New construction systems and processes - Modern methods of construction, Up skill industry to adopt new construction systems, Change outdated perceptions, Emerging technologies, What are the most appropriate BIM standards
Operating environment	Standards and conformance review and Building Act/Building Code

Research Drivers for Construction Sustainability	Outcomes/Way forward
Productivity	Industry structure, Productivity measures, Industry processes, Skills, Technology, Client value and Regulatory environment
Meeting the housing needs	Population change, Housing an ageing population, Housing a diverse Population, Meeting the needs of vulnerable groups, Housing tenure, Housing affordability
Building better cities and communities	How to deliver cities that meet the aspirations of residents, are affordable and liveable, while at the same time increasing density?, How can buildings enhance vibrant city environments, Integrate urban planning requirements at a city level with individual property rights, create cities and towns that work for current and future needs, given that the majority of future buildings and infrastructural assets are already in place
Agenda 21 for Sustainable Construction in Developing Countries – The Indian Case (Shah, 2002)	
Conservation of existing building stock	Extending the working life of buildings is a step towards sustainability as it reduces the need to construct new buildings.
Disaster mitigation Technologies	Protecting buildings from natural disasters is a part of conserving the building stock and therefore a step in sustainable construction. About 1.5 million buildings are estimated to be destroyed or severely damaged by the natural calamities every year. With about two thirds of the geographic area of the country disaster prone-- earthquake, flood, cyclone, landslides -- overall disaster preparedness and disaster resistant designs, detailing, technology and construction could save lives, structures and financial loss.
Land use	Sustainable land use is a precondition for sustainable construction: Land, being scare, non-elastic, and expensive and one of the most critical components in construction activity. Land conservation, optimal and creative use, equitable distribution and reuse of brown field areas are aspects of sustainable construction. A creative land ownership and use policy is a key determinant in sustainable construction.
Research Drivers for Construction Sustainability	**Outcomes/Way forward**
Work force	Productivity enhancing mechanization and modernization, in the form of tool transition, technology upgrading and changes in financing and management practices, in the sustainability context, must consider environmental, macroeconomic and social factors: conservation of natural resources, reduction of energy use and minimization of pollution (environment); labour intensive practices (macro-economy), and improving productivity, wages and welfare of construction workers (social). With a large population, massive poverty and high levels of unemployment and underdevelopment, it is vital that construction activity remains labour intensive without losing its competitive edge. This requires selective mechanization, skills upgrading, quality consciousness of construction workers and improvement in their working conditions. A low skill, low confidence, non motivated, poorly paid and exploited construction worker, a normal sight on many construction sites, is a serious threat to sustainable construction
Informal housing	Granting a place to the informal housing and settlements in the urban landscape and recognizing role of the peoples' processes in producing them, are vital to the sustainability of cities and construction. Cities will be unsustainable, if they negate, neglect or remain hostile to the resources, energy, creativity enterprise, and affirmative action of the poor.

Research Drivers for Construction Sustainability	Outcomes/Way forward
Gender equality	According women status as owners, recognizing their role as users and respecting their contribution, as producers is a move towards sustainable construction, settlement and development.
Professional education	Awareness and concern on sustainability issues and ways to integrate them into one's personal life style, living habits and economic pursuits need to be built in at all levels of education. Global-local interdependence is a cardinal principle of global sustainability. In achieving the goals of sustainable environment, construction and development, the attitude and actions of an individual, family, group and community are important. The basis for sustainable global economic and social system is a sustainable individual and family system. Education prepares a person for life. Consciousness building and training on sustainability should start there: in the primary and secondary school, in college education, and in professional training programmes.

The possibilities as well as the importance of above identified factors need to be tested in the Sri Lankan context through the field study. These urge for a change or a re-shape in academic research culture. A new research culture with better compatibility with the industry is the requirement which could also to be called as a user friendly research mechanism. Especially when it is to deal with a unique industry like construction there could be number of adjustments need to be bring in. The next part of this paper will summarize the theoretical background of the research issue which was discussed in detail within the paper together with a discussion on way forward for the research.

6. SUMMARY AND WAY FORWARD

Higher education is becoming a major driver of economic competitiveness in an increasingly knowledge-driven global economy. A university is a scholarly organism committed to inquiry, investigation and discovery at all levels with an embedded symbiotic relationship between teaching, research and practice. In addition to the primary duty of delivering good quality teaching, universities have another key responsibility: that is to add new knowledge to the wider society through research. Furthermore, the outcome of the research should serve educational needs and the development of the region and its economy. Therefore academic research has a role to play in promoting sustainable construction practices.

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 sustainable construction practices arising from research and development activities. This paper argues that the research conducted by university academics in the built environment discipline should be directed towards this industry need of sustainable construction practices. Therefore this literature review has identified the importance academic research in both the perspectives, in academic's view and in industry's view. Further it has identified the possible drivers for sustainable construction practice coming from research strategies developed for other countries in order to identify the directions and ability integrated in academic research. However, on the other hand, such literature therefore suggests the existence of better inter-relations between the academia and industry basically in developed countries.

Hence 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.

In order to achieve the aim, the objectives have been set as follows;

- Explore the nature of researches undertaken by construction related academics in Sri Lanka.
- Explore the construction industry development requirements in Sri Lanka.
- Explore the current link between academic research and industry practice with the reasons for existing gap.
- Develop guidelines to merge academic research with industry development requirements.

The aim with these objectives will be explored through a "mixed research method." As a research method, the mixed method focuses on collecting, analyzing, 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. In order to meet the first two objectives therefore two opinion surveys will be carried out. 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. Hence, a case study will be followed to achieve the third objective of the research. Based on the findings of the first three objectives, the final objective will achieved at the end. 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.

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SEARCH FOR KEY PERFORMANCE INDICATORS (KPIS) FOR TARGET COST CONTRACTS IN HONG KONG

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ABSTRACT

In view of the adversarial working relationships inherent with the traditional procurement method, Target Cost Contracts (TCC) and Guaranteed Maximum Price (GMP) contracts (being a variant of TCC), which align the individual objectives of various contracting parties together, would be appropriate integrated procurement models to cultivate more collaborative working atmosphere and partnering spirit within the construction industry. Different countries have already applied both TCC and GMP (TCC/GMP) schemes for several years. However, there exists a lack of published literature about the performance measurement of TCC/GMP projects worldwide, particularly in the Hong Kong context. In order to fill up this knowledge gap, this paper aims to identify those key performance indicators (KPIs) for TCC/GMP contracts in the construction industry of Hong Kong. Based on a series of various KPIs sought from a comprehensive desktop review, a two-round Delphi survey was launched with 14 industrial practitioners with direct hands-on experience in TCC/GMP construction projects in Hong Kong. A total of seven KPIs were identified in the survey. It was found that time, cost and quality are perceived as the typical KPIs for these kinds of projects. Moreover, the research findings reflected that relationship-based elements are also discerned as significant performance indicators such as mutual trust between project partners and contractor's involvement in project design, which play a vital role in project performance associated with TCC/GMP schemes as well. The identification of those KPIs has enhanced the understanding of project team members in implementing a successful TCC/GMP project.

Keywords: *Delphi Survey Method; Guaranteed Maximum Price Contracts; Hong Kong; Performance Measurement; Target Cost Contracts.*

1. INTRODUCTION

The problems associated with the traditional design-bid-build procurement method are often conducive to the adversarial working relationships (Kaka *et al.*, 2008; Lahdenpera, 2010). Both the Target Cost Contracts (TCC) and Guaranteed Maximum Price (GMP) contracts (being a variant of TCC) are considered to be the preferred options where project risks are taken jointly by the employer and the contractor. Sharing savings and losses depending on the final financial outcome of the projects make the contracting parties consider another side's view better and collaborate more efficiently. TCC and GMP (TCC/GMP) schemes have gained increasing popularity in the construction sector (Meng and Gallagher, 2012) across several countries such as the United States, the United Kingdom, Sweden and Finland for many years. However, an extensive desktop search indicated that there has been a lack of systematic empirical research into the performance measurement of TCC/GMP projects worldwide so far, especially in the Hong Kong context. To fill up this knowledge gap, this paper purports to search for a set of the key performance indicators (KPIs) to measure the performance of these procurement models.

The determination of KPIs for TCC/GMP projects is important in the project management and the continual improvement of performance of those TCC/GMP contracts and in enhancing the cost

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effectiveness of the whole procurement process. The aim of this study is to equip different key project stakeholders, including but not limited to employers, contractors and consultants, with the necessary knowledge and sound understanding about those KPIs inherent with TCC/GMP schemes. This study can also generate more valuable insights by adding to the existing body of knowledge and serving as a solid foundation for further studies on the performance measurement of TCC/GMP projects in future.

2. CONCEPTS OF TCC AND GMP

Twort and Ree (2004) advocated that a target cost contract is a contract in which the contractor shares a proportion of cost saving as a reward if the expenditure is less than the target cost, while he has to bear a proportion of cost overrun if he expends more than the target. Naoum (2003) shared a similar perception that target cost contract is a contract where a target cost is agreed and the contractor is reimbursed the costs, plus a fee. Any overrun or under run is shared in pre-agreed proportion. Wong (2006) proposed a computerized model for cost control of TCC contracts in Hong Kong and opined that TCC is a contract in which the contractor is paid the actual cost for the work done during the construction stage. When the final construction cost, termed the final total cost differs from the initial contract target cost, the difference would be shared between the employer and the contractor based on a pre-determined gain-share/pain-share ratio as stated in the contract. Hughes *et al.* (2011) pointed out that TCC is often referred to as a gain-share/pain-share arrangement in which the contracting parties specify an estimated cost (target cost) and sharing ratio which applies if the actual cost is higher than or lower than the estimated cost. They also advocated that TCC is justified to be used when: (1) the client is incentivised actively to help the contractor to search for cost-efficient solutions; and (2) the client deliberately chooses the same contractor for repeated business.

The American Institute of Architects (AIA) (2001) viewed GMP as a sum established in an agreement between a client and a contractor as the cap of overall project cost to be paid by the client to the contractor for performing specified works on the basis of the cost of labour and materials plus overhead and profit. The contractor receives a prescribed sum, along with a share of any savings to the client under this procurement approach. If the cost of the works exceeds the assured maximum, the contractor bears the excessive costs (Walker *et al.*, 2000). Under this situation, a ceiling price is established, and the contractor is solely responsible for any additional costs (Gould and Joyce, 2003).

In fact, GMP is perceived as a TCC with an additional feature that the maximum amount to be paid to the contractor by the employer is capped (Hughes *et al.*, 2011); and GMP is a variant of TCC according to Masterman (2002). So TCC and GMP are lumped together in previous research studies for analysis (e.g. Chan *et al.*, 2007a, 2007b, 2010). As a result of the similar nature of TCC and GMP contracts and their practices derived from previous research studies, both TCC and GMP are placed together for subsequent analyses and discussions herein.

3. PERFORMANCE OF TCC/GMP CONTRACTS

Scholars have shared mixed views on the effectiveness of TCC/GMP schemes. Hughes *et al.* (2011) opined that the TCC contractual arrangement may not incentivise the contractors to save cost. However, Chan *et al.* (2007b) reported on the key findings of eight face-to-face interviews and concluded that providing financial incentives for the contractors to achieve cost savings and innovate is one of the perceived benefits of TCC/GMP contracts. It would be interesting and essential to look into the actual performance outcomes of TCC/GMP construction projects worldwide. Payment methods in construction contracts can be analysed from the perspective of incentives or disincentives. Cost incentives encourage saving which may be more effective for cost control in practice, while cost disincentives discourages overspending (Meng and Gallagher, 2012). If cost incentives are combined with cost disincentives, the joint effect is remarkable and this may be the main reason for introducing GMP contracts.

In the United Kingdom and the Republic of Ireland, Meng and Gallagher (2012) conducted a questionnaire survey in order to analyse the relationship between the use of incentives and the performance outcomes of 60 completed construction projects. The study compared the projects under four different payment methods including: (1) fixed-price contracts; (2) target cost contracts; (3) cost-plus-fee contracts; and (4) contracts in which payment is based on final outcomes. The study revealed that target cost contracts performed better than cost-plus-fee contracts and contracts in which payment is based on final outcomes in terms of cost certainty. In terms of cost performance, target cost contracts also performed more favourably than these two kinds of payment methods. According to the statistics of the National Health Service (NHS) (2011), the 97% of the TCC projects under the ProCure 21+ Framework in 2010 achieved the final cost to budget or within budget. In the United States, Rojas and Kell (2008) investigated around 300 school projects located in the Northeast part of the United States. The actual project cost exceeded the GMP value in 75% of the cases. They concluded that GMP may not be an effective guarantor of construction cost in practice. In contrast, Bogus *et al.* (2010) conducted an extensive analysis of the performance data of public water and wastewater facilities in the United States. Their study advocated that contracts using cost-plus-fee method with the GMP arrangement performed better in terms of cost and schedule in comparison with those with lump-sum contracts.

4. Delphi Survey Technique

The Delphi survey technique was originally developed by the RAND Corporation for studying the impact of warfare (Hallowell and Gambatese, 2010). According to Hasson *et al.* (2000), a Delphi survey is regarded as a group facilitation technique, designed to transform opinions into group consensus. This technique allows researchers to maintain a significant degree of control over bias in a well-structured academically rigorous process, according to the judgment of qualified experts (Hallowell and Gambatese, 2010). The Delphi method is considered as 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). Individual experts are requested to participate in two or more rounds of structured surveys. An anonymous result summary of opinions of the group of experts from the previous round is provided to each of the experts, and they are invited to review the overall group results and consider whether to revise their previous responses or not. The objective of this process is to decrease the variability of the responses and to achieve group consensus and correct value. Delphi method can offer a merit in situation where it is important to define areas of uncertainties or disagreements amongst experts. The Delphi technique is therefore appropriate for obtaining a series of the most important KPIs for evaluating the success of TCC/GMP construction projects (Chan *et al.*, 2001).

5. Development of Delphi Survey Questionnaire

The questionnaire used in the Delphi survey was developed based on a comprehensive desktop review of the KPIs to evaluate the success of construction projects worldwide. The previous studies on performance measurement in construction were reviewed from contemporary literature (KPI Working Group, 2000; Cox *et al.*, 2003; Swan and Kyng, 2004; Cheung *et al.*, 2004; Menches and Hanna, 2006; Jones and Kaluarachchi, 2007; Lam *et al.*, 2007; Luu *et al.*, 2008; Rojas and Kell, 2008; Tennant and Langford, 2008; De Marco *et al.*, 2009; Toor and Ogunlana, 2009). Finally, a total of 15 KPIs were identified on the survey questionnaire and they are listed below: (1) Time required for the settlement of final project account; (2) Time performance; (3) Mutual trust between project partners; (4) Percentage of contractor's alternative design proposals approved by consultants in first go; (5) Final out-turn cost exceeding the final contract target cost or guaranteed maximum price value or not; (6) Magnitude of disputes and conflicts; (7) Cost per m^2 of construction floor area (CFA) including foundations; (8) Client's satisfaction on quality of completed work; (9) Contractor's satisfaction on TCC/GMP contractual arrangement; (10) Contractor's involvement in project design; (11) Contractor's feedback on client's decision making process; (12) Design quality; (13) Environmental friendliness; (14) Safety performance; and (15) Time needed from commencement of project design up to contract award. These 15 KPIs elicited on the survey form were then properly verified by some senior industrial practitioners with extensive hands-on experience in TCC/GMP projects, and they were all confirmed to be sufficient, representative and appropriate for use.

5.1. FORMAT OF DELPHI ROUNDS

Two rounds of Delphi survey exercise were performed from March to May of 2011. As pointed out by Mullen (2003), two or three rounds of Delphi survey are preferred and found in a significant number of previous studies. In this study, the main reason for launching two rounds of Delphi survey only is to minimise the fatigue and attritions of experts in repeated rounds but can allow feedback and revision of responses. Design of the questionnaire for Round 1 was based on a comprehensive review of published literature pertaining to the performance measurement of construction projects in general and available materials about TCC/GMP schemes in particular. In Round 1, the respondents were requested to select a minimum of five but a maximum of ten KPIs from a consolidated list of 15 various key performance measures which were considered as the most vital KPIs to evaluate the success of TCC/GMP projects in Hong Kong. They were also welcome to insert additional indicators if deemed appropriate. Round 2 of the questionnaire survey was related to all the KPIs provided on the questionnaire from Round 1, in addition to those KPIs suggested by the panel of experts in Round 1. After Round 1, the results were consolidated and then presented to the expert panel in Round 2. They were requested to freely adjust their original options in Round 2 if necessary.

5.2. SELECTION OF THE EXPERT PANEL

The success of a Delphi survey highly depends on the careful selection of experts (Chan *et al.*, 2001). A group of experts were selected to provide their opinions on the KPIs for TCC/GMP construction projects in Hong Kong. A purposive sampling approach was adopted to select the group of experts since the experts should have gained in-depth knowledge about TCC/GMP contracts and sound hands-on experience in the construction industry. The following criteria were set out to search for the eligible participants for this Delphi survey: (1) Participants should have extensive working experience of at least 10 years in the construction industry of Hong Kong; (2) Participants should have been engaged in at least one TCC/GMP construction project before in Hong Kong; and (3) Participants should hold a position of at least a professional grade in the TCC/GMP projects concerned. Only those industrial practitioners who have fulfilled all of the three criteria above were invited to participate in this Delphi survey, in order to obtain most valuable insights and representative opinions from them.

6. DELPHI SURVEY ROUND 1: IDENTIFYING THE MOST IMPORTANT KPIS

The questionnaire of Round 1 was developed based on a comprehensive literature review. The questionnaire together with an invitation letter, which explained the purpose of the research study, were dispatched to the 72 potential target respondents via postal mail in March of 2011, as identified from previous research studies on TCC/GMP schemes in Hong Kong (Chan *et al.*, 2007b; Chan *et al.*, 2011). A total of 16 practitioners ultimately participated in this study. The sixteen members of the expert panel represented a wide spectrum of construction professionals: three from client organisations, ten from contractor companies and three from consultant firms. The composition of the expert panel provided a holistic, balanced view for this Delphi study. Table 1 serves as a summary of their personal profiles.

The experts were requested to choose a minimum of five but a maximum of ten KPIs for TCC/GMP projects from a summary list of 15 KPIs provided on the survey form. They were also welcome to provide additional KPIs for TCC/GMP contracts in Hong Kong wherever deemed appropriate. Six additional KPIs suggested by the expert panel were carefully analysed. Table 2 lists out all the KPIs (i.e. 15 originally identified from the literature review and 6 additionally suggested by the expert panel) in Round 1 of the Delphi survey. Their frequencies of hit are also indicated in the same table.

7. DELPHI SURVEY ROUND 2: REFINING THE SELECTED KPIS

The questionnaires of Round 2 were mailed to the same group of panel experts in May of 2011. In this round, the results of Round 1 were consolidated and presented to the experts and they were requested to reconsider whether they would like to change any of their original choices or not after second thought, in light of the consolidated results from Round 1. Only 7 experts returned their completed questionnaires within a planned deadline of two weeks.

An electronic mail was individually sent to remind all the experts who had not yet returned their completed questionnaires, followed up a phone call if necessary. Finally, 14 out of the 16 experts returned their completed forms towards the end of May 2011. Two experts were unable to participate in the survey because of their heavy workload at that time.

Table 1: Personal Profiles of the Delphi Expert Panel

Expert	Position	Role	Years of Working Experience in Construction Industry	Hands-on Participation in at Least One TCC/GMP Project
1	Assistant Project Director	Client	More than 20 years	Yes
2	Partner	Consultant	16-20 years	Yes
3	Construction Manager	Contractor	16-20 years	Yes
4	Contract Advisor	Contractor	11-15 years	Yes
5	Project Manager – Contract and Cost	Contractor	More than 20 years	Yes
6	Engineer	Contractor	More than 20 years	Yes
7	Engineer	Contractor	More than 20 years	Yes
8	Commercial Manager	Contractor	More than 20 years	Yes
9	Construction Manager – Estimating and Subletting	Contractor	More than 20 years	Yes
10	Estimation Manager	Contractor	16-20 years	Yes
11	Contracts Manager	Contractor	More than 20 years	Yes
12	Commercial Manager	Contractor	More than 20 years	Yes
13	Technical Director	Consultant	16-20 years	Yes
14	General Manager (Contracts)	Contractor	More than 20 years	Yes
15	Quantity Surveyor	Client	More than 20 years	Yes
16	Contract Advisor	Client	More than 20 years	Yes

As observed from Table 3, there are altogether seven KPIs with a frequency percentage of 50% or higher selected by the Delphi panel of experts. Hence a total of seven most important KPIs were identified specifically for measuring the performance of TCC/GMP construction projects in Hong Kong. After two rounds of Delphi survey, it was found that the top seven KPIs for TCC/GMP projects in Hong Kong emphasise project success, relationships and people in broad terms, which are briefly discussed below.

MUTUAL TRUST BETWEEN PROJECT PARTNERS

All of the 14 panel experts believed "Mutual trust between project partners" to be a vital KPI for TCC/GMP schemes. Nystorm (2008) pointed out that most partnering projects applied the underlying concepts of a target cost-based contract. It is not possible to formally separate the role of partnering from the role of TCC. Wong and Cheung (2005) advocated that the establishment of mutual trust is essential to partnering success. Black *et al.* (2000) carried out partnering studies and concluded that the cultivation of mutual trust among partners is instrumental to the successful implementation of partnering. Partnering is often introduced in parallel to TCC/GMP contracts in Hong Kong as reported by Chan *et al.* (2007a) and Anvuur and Kumaraswamy (2010). Another similar study by Yeung *et al.* (2007) on evaluating the success of partnering projects in Hong Kong via a Delphi study also recommended that "mutual trust and respect" is one of the important KPIs for partnering projects in Australia.

Table 2: Results of Round 1 Delphi Survey

	Key Performance Indicators for TCC/GMP Projects	Total Frequency	Percentage
1.	Mutual trust between project partners	15	93.75
2.	Time performance	14	87.50
3.	Magnitude of disputes and conflicts	11	68.75
4.	Final out-turn cost exceeding the final contract target cost or guaranteed maximum price value or not	11	68.75
5.	Client's satisfaction on quality of completed work	11	68.75
6.	Contractor's feedback on client's decision making process	9	56.25
7.	Time required for the settlement of final project account	10	62.50
8.	Contractor's involvement in project design	8	50.00
9.	Design quality	8	50.00
10.	Time needed from the commencement of project design up to contract award	6	37.50
11.	Percentage of contractor's alternative design proposals approved by consultants in first go	6	37.50
12.	Safety performance	5	31.25
13.	Contractor's satisfaction on TCC/GMP contractual arrangement	6	37.50
14.	Environmental friendliness	2	12.50
15.	Cost per m^2 of construction floor area (CFA) including foundations	1	6.25
16.	*Form of contract to be used*	1	6.25
17.	*Contractor's ability to perform cost management*	1	6.25
18.	*Appropriateness of risk allocation*	1	6.25
19.	*Time allowed for pre-construction preparation works*	1	6.25
20.	*Contractor's claim consciousness attitude*	1	6.25
21.	*Amount of works that the tenderer has in hand at the final stage of tendering*	1	6.25

Note: Additional KPIs suggested by the expert panel are indicated in *italics*.

TIME PERFORMANCE

As previously stated in literature review, "Time performance" is regarded as one of the common KPIs worldwide (KPI Working Group, 2000; Menches and Hanna, 2006). This KPI is also similar to "time certainty" as suggested by NHS ProCure21+ Guide (2011). Lam *et al.* (2007) considered time to be one of the KPIs for design-and-build construction projects in Hong Kong. Frampton (2003) opined that TCC/GMP procurement strategies allow early commencement of construction activities before design is fully completed. It would be interesting to see if TCC/GMP contracts outperform the others in terms of time certainty.

FINAL OUT-TURN COST EXCEEDING THE FINAL CONTRACT TARGET COST OR GUARANTEED MAXIMUM PRICE VALUE OR NOT

The main feature of TCC/GMP schemes is to incentivise the contractor to achieve cost savings by aligning the individual interests of the employer and those of the contractor together (Rose and Manley, 2010). It is logical that the cost performance of TCC/GMP projects (i.e. whether final out-turn cost exceeding the final contract target cost or guaranteed maximum price value or not) constitutes a significant KPI for this kind of projects like Chan *et al.* (2011).

Table 3: Results of Round 2 Delphi Survey

	Key Performance Indicators for TCC/GMP Projects	Total	Percentage
1.	**Mutual trust between project partners**	**14**	**100.00**
2.	**Time performance**	**12**	**85.71**
3.	**Final out-turn cost exceeding the final contract target cost or guaranteed maximum price value or not**	**11**	**78.57**
4.	**Magnitude of disputes and conflicts**	**10**	**71.43**
5.	**Client's satisfaction on quality of completed work**	**10**	**71.43**
6.	**Time required for the settlement of final project account**	**10**	**71.43**
7.	**Contractor's involvement in project design**	**10**	**71.43**
8.	Contractor's feedback on client's decision making process	6	42.86
9.	Design quality	6	42.86
10.	Time needed from the commencement of project design up to contract award	6	42.86
11.	Percentage of contractor's alternative design proposals approved by consultants in first go	4	28.57
12.	Safety performance	4	28.57
13.	Contractor's satisfaction on TCC/GMP contractual arrangement	3	21.43
14.	*Contractor's ability to perform cost management*	2	14.29
15.	*Appropriateness of risk allocation*	2	14.29
16.	*Contractor's claim consciousness attitude*	2	14.29
17.	*Form of contract to be used*	1	7.14
18.	*Time allowed for pre-construction preparation works*	0	0.00
19.	*Amount of works that the tenderer has in hand at the final stage of tendering*	0	0.00
20.	Environmental friendliness	0	0.00
21.	Cost per m^2 of construction floor area (CFA) including foundations	0	0.00

Notes: (1) Additional KPIs suggested by the expert panel are indicated in *italics*; and (2) KPIs with percentage of 50% or higher are highlighted in **bold**.

MAGNITUDE OF DISPUTES AND CONFLICTS

This finding is consistent with Lam *et al.* (2007) and Toor and Ogunlana (2010). TCC/GMP projects are usually implemented in parallel to partnering spirit (Chan *et al.*, 2007a). It was suggested that partnering can be perceived to be a useful means to transform the contractual relationship into a cohesive, integrated project team with common goals and clear procedures for resolving disputes and conflicts in a timely and effective manner (Bench *et al.*, 2005). It would be important to evaluate whether TCC/GMP procurement strategies could effectively reduce disputes or disagreements between contracting parties.

CLIENT'S SATISFACTION ON QUALITY OF COMPLETED WORK

Quality is referred to as conformity to contract specifications and client's satisfaction on constructed facilities. It is always ranked among the top priorities of construction projects (Soetanto *et al.*, 2001). Not surprisingly, the quality of completed work was chosen as a KPI for TCC/GMP projects. The same has been widely reported in other literature on the performance measurement in construction (Cheung *et al.*, 2004; Lam *et al.*, 2007).

TIME REQUIRED FOR THE SETTLEMENT OF FINAL PROJECT ACCOUNT

A research study undertaken by Yiu *et al.* (2005) evaluated the performance of consultants in the construction industry of Hong Kong at four different stages, namely: (1) design/planning stage; (2)

tender stage; (3) construction stage; and (4) final account stage. The last stage (final account stage) recognises the settlement of final account contributing to the success of a construction project. Early settlement of final project account is regarded as one of the perceived benefits of employing the TCC/GMP forms of procurement (Chan *et al.*, 2007b). This KPI "Time required for the settlement of final project account" would be useful for gauging TCC/GMP projects for whether they can materialise this benefit.

CONTRACTOR'S INVOLVEMENT IN PROJECT DESIGN

The significance of integrating the construction expertise into the design process has been recognised by the construction industry (Song *et al.*, 2009). Mosey (2009) shared a similar perception that design contributions should not be made by design consultants only, but also by main contractors and specialist suppliers to achieve a complete and functional design. This aspect is particularly important in TCC/GMP construction projects, since in many cases the main contractors have been involved at an early stage of project delivery (Chan *et al.*, 2007a). The contractor's involvement in project design would probably affect the project outcomes in terms of time, cost, quality and buildability.

8. CONCLUSIONS

Through a two-round Delphi survey, a total of seven KPIs were sought specifically for TCC/GMP construction projects in Hong Kong. The identified KPIs consist of: (1) Mutual trust between project partners; (2) Time performance; (3) Final out-turn cost exceeding the final contract target cost or guaranteed maximum price value or not; (4) Magnitude of disputes and conflicts; (5) Client's satisfaction on quality of completed work; (6) Time required for the settlement of final project account; and (7) Contractor's involvement in project design. Apart from the traditional KPIs about time, cost and quality, the remaining four KPIs substantially focus on the collaborative relationship between the employer and the contractor. The identification of the KPIs has enhanced the understanding of project team member to implement a successful TCC/GMP construction project. The research findings from this study reflected that relationship-based issues such as mutual trust and contractor's involvement in project design play an important role for the performance of this kind of projects. This study has explored the area of performance measurement of TCC/GMP construction projects in Hong Kong by determining the KPIs via a two-round Delphi survey. Further research could be launched to investigate the relative importance of the respective KPIs sought and then formulate a composite index to gauge the overall performance levels of TCC/GMP construction projects in both Hong Kong and overseas.

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SPECIAL FEATURES, EXPERIENCES AND NEW TRENDS IN ARBITRATION IN THE CONSTRUCTION INDUSTRY OF SRI LANKA

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ABSTRACT

In Sri Lanka, Alternative Dispute Resolution (ADR) methods such as negotiation, conciliation, mediation, adjudication and arbitration can be identified as preferable alternatives for replacing traditional litigation as they would be more effective in time and cost. Arbitration is a voluntary procedure available as an ADR method to litigation. The main feature of arbitration is that it is consensual in nature and private in character. Arbitration Act of Sri Lanka No 11 of 1995 stated that arbitration principles and contents are based on UNCITRAL Model Law. At present, many parties to construction disputes have no interest in pursuing for arbitration. Therefore, professionals should take collective measures to increase the effectiveness of arbitration. With the increase in construction activity after 30 years of civil war the construction industry of Sri Lanka needs a fast and cost effective dispute resolution method. The aim of this research is to critically evaluate the arbitration method, its experiences and new trends as an ADR method in the construction industry of Sri Lanka, and suggest improvements to its practice in order to make arbitration procedure more effective. The research is to develop arbitration as an effective and efficient ADR method in the Sri Lankan construction industry.Literature review for the research was carried out together with the survey. The questionnaire survey was used among construction industry professionals. Accordingly, data collection was selected only from experienced professionals in the industry. This research is limited to the arbitration in the construction industry of Sri Lanka.

The findings of the research indicate that the professionals who are involved in the construction industry have low level of satisfaction on the current practice of arbitration. However, they believe that arbitration is an effective mechanism for dispute resolution in Sri Lankan construction industry. The results of this study enable researchers to gain an understanding of the current arbitration practice and recognise significance of advantages, drawbacks and suggestions for the development of arbitration in the construction industry of Sri Lanka.

Keywords: *ADR Methods; Arbitration; Construction Industry; Dispute Resolution.*

1. INTRODUCTION

The construction industry forms a major sector of Sri Lankan economy. It directly affects the economic growth. Disputes are common features of the construction industry (Ashworth, 2002). Disputes might arise at any point during the construction process. Construction industry creates a multitude of disputes due to its various inherent characteristics. In early days of construction industry in Sri Lanka, most disputes were settled amicably on the site at an informal meeting between the client and contractor with resident engineer. However at present construction disputes are more lengthy and complicated than ordinary civil cases in Sri Lanka.

It can be seen that employers, contractors, and consultants resort to various approaches in their attempt to resolve disputes. Such approaches may bring short term benefits to parties. However, long term effects as a result cannot be ruled out. The professionals should persuade stakeholders to adhere to the fundamentals of arbitration, law and ethics in the process of dispute management and resolution in order to have a more sustainable and healthy construction industry.

According to the literature review on dispute resolution, it is found that ADR methods that many have stated that it is sometime a wastage of time, cost and effort as the involved parties is unable to come to an agreement in their decisions. It is also seen that arbitration method has drawbacks and pitfalls apart from their respective advantages.

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1.1. Aim of the Research

The aim of this research is to critically evaluate the arbitration method as an alternative to dispute resolution practice, evaluate the effectiveness of arbitration method in the Sri Lankan construction industry and suggest improvements to the construction arbitration in Sri Lanka in order to make arbitration more effective and viable.

1.2. Objectives

To accomplish the above aim following objectives were identified,

- To explore the image of arbitration as an ADR method and its level of satisfaction.
- To find out problematic areas of construction arbitration in Sri Lankan industry.
- To evaluate the applicability and the effectiveness of the arbitration method as an alternative to litigation in the Sri Lankan construction industry.
- To analyse the current arbitration process, advantages and disadvantages along with the arbitration procedure.
- To develop required improvements in arbitration practice to achieve an efficient performance and enhance the satisfaction in the Sri Lankan construction industry.

1.3. Research Methodology

To accomplish the above aim and objectives, a literature review was conducted to find out the available research gaps and the extent to which research has been carried out on arbitration. The developed research questionnaire used to gather data from the construction industry professionals who are closely engaged with construction activities and the collected data was analysed using statistical tools.

1.4. Scope and Limitations

This research was limited to evaluate the arbitration method and its practice as an ADR method in the construction industry in Sri Lanka. The unit of analysis of the research was the dispute-resolving experts in the construction industry mainly consisting of experienced professionals in the organizations.

2. Literature Review on Disputes Resolution Methods in the Construction Industry

The literature review is one of the core components in a research process. Accordingly this part has been mainly focused on the arbitration practice in the construction industry of Sri Lanka. In addition the literature review has been narrowed to the identifying of conflicting areas in the construction arbitration.

2.1. Litigation as a Dispute Resolution Method

''Discourage litigation. Persuade your neighbours to compromise whenever you can. Point out to them how the nominal winner is often the real loser-in fees, expenses, and waste of time''

- Abraham Lincoln
(Ide, 1993)

Above statement is universal and litigation is the standard and conventional dispute resolution mechanism used all over the world. Litigation as dispute resolution method has been criticises due to the adversarial nature, high cost and time consuming characteristics. According to previous studies litigation have not been found to be a suitable method for dispute resolution in construction industry. It is too expensive and a time consuming method. Also, there are several disadvantages in litigation like stressfulness, inflexibility and formality of court processes, restricted scope of claims and remedies as well. Construction industry professionals face the aforesaid difficulties. Hence they commenced finding alternative dispute resolution (ADR) methods. In **State of Kerala, India vs. Joseph Auchilose** [1], the Indian court observed that complex and expensive court procedure compelled jurists to search for an alternative form of resolution of disputes. Ashworth (2002) has identified litigation as an unsuitable method for dispute resolution in construction industry.

Therefore, the industry expects an efficient and successful dispute resolution method as an alternative to the adversarial litigation process. Construction industry around the world has been complex or varied and is proving to be more complex in the time to come. Due to the complexity, disputes are considered to be inevitable in construction industry. Therefore resolution of disputes has become a noteworthy area of construction industry research.

3. ARBITRATION AS AN ALTERNATIVE DISPUTE RESOLUTION METHOD

ADR methods arose in the last two decades as a response to the aforesaid disadvantages *viz* confidentiality, high cost and lengthy process associated with litigation. According to Brooker (1999), arbitration is an ADR method which has a flexible process conducted confidentially in which a neutral person actively assists parties in working towards a negotiated agreement of a dispute with the parties. Furthermore, Cheung *et al.* (2000) identified some main unique characteristics of arbitration as confidentiality, preservation of business relationship, cost and time saving, flexibility, voluntariness, generation of creative agreement, neutrality, fairness and high levels of satisfaction which could be directly or indirectly overcome drawbacks in arbitration methods. The construction industry uses arbitration as its principal final mode of dispute resolution (Sims *et al*., 2003). It can be considered as a suitable mechanism for many construction industry disputes. Despite its decline, arbitration is still the preferred method of final dispute resolution in the construction industry. (Sims *et al*., 2003, p.550).

3.1. ARBITRATION PRACTICE IN SRI LANKA

With the introduction of the Arbitration Act No. 11 of 1995, construction disputes are more likely to move towards the arbitration in Sri Lanka. The Arbitration Act of Sri Lanka No. 11 of 1995 provides a legislative framework for the effective conduct of arbitration proceedings. (Wimalachandra, 2007)The objectives are stated in the preamble of this Act, one of its objects is to make “Comprehensive legal provisions” for the conduct of arbitration proceedings and the enforcement of arbitral awards. The second object is to make legal provision to give effect, to the principles of the Convention on the recognition and enforcement of foreign award of 1958 (The New York Convention). About 120 countries have signed the New York Convention and it facilitates enforcement of foreign arbitral awards in all contracting states including Sri Lanka.

The arbitration institutions such as Institute for Development of Commercial Law and Practice (ICLP), Sri Lanka National Arbitration Centre (SLNAC) and International Chamber of Commerce Sri Lanka (ICCSL) provide better infrastructure for arbitration practice. Arbitration plays a major role in commercial matters (Kanag-lsvaran, 2006)**.** Kanag-Isvaran (2006) identified, enhancing its finality, waive appeal by exclusion agreement, limited court intervention, party autonomy, recognition and enforcement of award are as basic elements of the Act. In the construction industry each individual contract contains a degree of uniqueness even though the contracts may be based upon standardised forms. The construction industry has generally used arbitration rather than civil courts as the means of settling any disputes which arise between the contractor and the employer. These arise because the disputes are more generally of a technical nature and the parties are happier to refer their disputes to an expert who understand the technical problems involved and who could bring other knowledge of usual practices of the industry to the formation of his or her judgment.

The Arbitration Act of Sri Lanka No. 11 of 1995 treats arbitration in the field of construction without taking in to consideration the value of contract or the disputed amount. In Sri Lanka arbitration is the only legally enforceable ADR method backed by the Act. The Act was enacted as a comprehensive

Act on arbitration to replace the outdated legislation in existence, which was inadequate to settle disputes through arbitration. The Sri Lanka Act provides that an arbitration agreement shall be in writing. It can be contained in a single document or in an exchange of letters, telexes, telegrams or other means of telecommunication which provide records of the agreement. It mentions challenges to jurisdiction, duties of the arbitrators, corrections and interpretation etc. Accordingly, Sri Lankan Act to a great extent follows the UNCITRAL Model Law.

This Act in itself does not lay down any rules of Arbitration. However, Act deals with the composition of the arbitral tribunal, the jurisdiction of the arbitral tribunal, the conduct of arbitral proceedings, awards, enforcement of awards, recognition and enforcement of foreign arbitral awards and grounds for refusing or enforcement of awards. Due to the absence of strict rules of arbitration provided by the Act, parties are free to choose the rules under which their arbitration should be conducted. According to the Section 32 (1) (a) of the Act, it expressly states the grounds on which such an order can be set aside.

The construction industry appears to favour the resolution of disputes by arbitration proceedings. These proceedings enable a determination by a respected person usually from a discipline apart-from the dispute, and will be resolved in a manner, which reflects the contractual and commercial aspects of the project. Applicable law will be the Sri Lankan Law and the proceedings should be held in the English language. Therefore parties can carefully draft an arbitration agreement to include arbitration clauses. It has to be done after careful scrutinising of the clauses that are in English language. When there is an arbitration clause, grieved parties concerned cannot seek a remedy in courts because in such case the jurisdiction is not considered by virtue of the arbitration agreement.

3.2. CONDITIONS OF CONTRACTS RELATING TO ARBITRATION PRACTICE

Standard forms of contract published by the Institute of Construction Training and Development of Sri Lanka (ICTAD, 2007) is the most popular standard form used in Sri Lanka. It provides an arbitration clause for settlement of construction disputes through their Conditions of Contracts document. According to the arbitration agreement recommended by ICTAD (clause 67) the period for commencement of arbitration must take place within a maximum of 90 days. Clause 48.1 of the Standard Bidding Document (SBD) of the ICTAD (Guidelines of the Government of Sri Lanka) (2007) provides Arbitration clause for construction contracts.

According to the ICTAD (2007) conditions of contract the adjudicator shall be a single person appointed by agreement between the parties. If parties are unable to reach the agreement within 14 days of such request of agreement, the adjudicator shall be appointed by the ICTAD. Either party may initiate the reference of the dispute to the adjudicator by giving 07 days notice to the other party. Then the adjudicator shall give his determination about the dispute within 28 days -or such other period agreed by the parties- of receipt of such notification of a dispute. This is very tight time scale as it may work in favour of the claimant because he will be able to prepare his case over sometime, while giving short time scale to in the other party. On the other hand, these time restrictions give some advantage of immediate, inexpensive dispute resolution mechanism.

On the other hand ***Federation Internationale Des Enginieurs*** (FIDIC) document, which is another popular standard form, states that the maximum period to appoint an arbitrator is 154 days to arrive at the final decision (Bunni, 2003). In Sri Lanka all disputes arising out of contracts should be dealt with in accordance with the provisions of Arbitration Act No: 11 of 1995. However, Sri Lankan Arbitration Act does not specify a time limit. FIDIC conditions of contract of 1999 have introduced Dispute Adjudication Board (DAB) system as a pre-Arbitration requirement. Accordingly, Clause 20 of FIDIC 1999 dispute between employer & contractor shall be referred to Dispute Adjudication Board as a pre-Arbitral step before reference same for arbitration –When there is no settlement before DAB only the same dispute can be referred for Arbitration.

4. PROBLEMATIC AND CONFLICTING AREAS SPHERES OF ARBITRATION

Sri Lanka Arbitration Act - No 11 of 1995 states arbitration principles and elements of UNCITRAL Model Law. However, out of all ADR methods, arbitration is the commonly practicing ADR method in the Sri Lankan construction industry. When practicing arbitration as an ADR method, a third party neutral render a decision based on information submitted by the dispute parties, following the same manner as in the traditional legal trial (Marsoof, 2006). Dissatisfaction with arbitration within the construction industry has been perceived to have complexity, slowness and expense. Many legal researchers stated that Sri Lankan arbitration process has become adversarial and expensive. Therefore it is necessary to review and improve the arbitration practice periodically in order to minimise the cost and complexity of the procedure. Arbitration is the commonly practicing ADR method however; it has many unique drawbacks when practicing arbitration. Research findings have indicated drawbacks of Sri Lankan arbitration, as delaying the process, high cost of arbitrators and other facilities, higher involvement of lawyers, less concentration on technical issues, unawareness, different resolutions given by different arbitrators, difficulty in challenging the award, inability to conduct multi party disputes using arbitration and limited jurisdictions, same procedure being applied for all disputes, impossibility of maintaining the relationship between parties, less satisfaction with the process. Further most professionals not being fully aware of the arbitration process. Also, there are no facilities to conduct arbitration other than in Colombo the commercial capital city in Sri Lanka.

The serious criticisms against the arbitrations in Sri Lanka are the time factor. The Arbitration agreement incorporated by the ICTAD in the Conditions of the Contact under clause No. 67 stipulates that the period within which the award should be made is 4 months, although the Arbitration Ordinance of 1948 stipulates a period of 3 months. However, present Arbitration Act does not specify a time limit. Parties are free to fix a desired time period for proceeding and award of the agreement. However, there may be an extension with the consent of the parties. According to the arbitration agreement recommended by ICTAD the period for commencement of arbitration must take a maximum period of 90 days and in accordance with the FIDIC - Conditions of Contracts the maximum period to appoint an arbitrator is 154 days. Hence the time factor remains a major drawback in the arbitration process.

There are important provisions for speedy arbitration hearings during the course of the contract under Rule 07 of the JCT Arbitration Rules. However, the experience of arbitrators themselves is that they are little used. Some countries in the Middle East with which Sri Lankan contractors have entered into construction contracts, are not parties to New York Convention and they all have resort to other regional arrangements such as the *Amman Arbitration Convention* which requires all arbitral proceedings to be conducted in the Arabic language.

5. NEW TRENDS OF ARBITRATION IN SRI LANKA

In Sri Lanka the arbitration process is conducted in two ways. The *ad-hoc* arbitration is conducted when the parties decide on their own procedure to be adopted in the conduct of the arbitration proceedings. It is observed that most domestic construction contracts are conducted on *Ad-hoc* procedure. Arbitral institutions under its own rules of arbitral procedure conduct the *Institutional* arbitration. It provides the framework of rules and such other facilities for entire proceeding. However any aggrieved party can challenge arbitral award at Commercial High Court.

Most Arbitration Acts of the world (including those following the UNCITRAL Model law) usually allow parties to change the substantive law to be applied, if it is a transactional contract. The Arbitration Act of Sri Lanka (Act No: 11 of 1995) goes a little further. The Sri Lankan courts refused to incorporate the arbitration agreement into a subcontract. The Courts of Law in Sri Lanka examined and interpreted the language of the contracts in question to see whether general principles of arbitration are applicable. Arbitrators may keep away from writing reasons for the award and only the final decision of the arbitrators will be enough for a valid award. This will be very useful for the settlement of disputes relevant to construction industry.

Many Researchers in Sri Lanka stated that arbitration process has become adversarial and expensive. However, superior courts of Sri Lanka reviewed and improved the arbitration process. There are some cases which were decided by Superior Courts of Sri Lanka and now those have become a part of arbitration law as a judicial precedent. Accordingly, case law developed arbitration procedure of Sri Lanka. In ***Southern Group Civil Construction (Pvt) Limited vs. Ocean Lanka (Pvt) Limited*** **[2]**, the Court discussed and interpreted the grounds for setting aside an arbitral award and the time limitation for challenge the arbitrator's award. This was an application for setting aside arbitral award under section 32 of the Arbitration Act of Sri Lanka. In ***State Timber Corporation vs. Moiz Goh (Pvt) Ltd.*** **[3]**, court held that the District Courts of Sri Lanka has no jurisdiction to enter in to the arbitration proceedings.

When there is an arbitration clause the aggrieved parties concerned cannot seek a remedy in courts because in such case the jurisdiction is waved by virtue of the arbitration agreement. It was held in the case of **Lanka Orient Leasing Company Ltd vs Ali and another [4]. Mahaweli Authority of Sri Lanka vs. United Agency Construction (Pvt.) Ltd. [5]** case was an appeal to the Supreme Court from an order of the Commercial High Court under section 37 of the Arbitration Act No: 11 of 1995. The Supreme Court decided that the time period necessary for leave to appeal. The need to set out in the application the grounds for setting aside the award period for making the application – whether grounds set out in written submission after lapse of that period can be considered.

6. ANALYSIS AND RESEARCH FINDINGS.

After identifying the research problem, a comprehensive literature review was conducted to explore the legal framework of Arbitration. The literature review was carried out mainly by referring books, Statutes and journal articles. The literature review focused more on the publications by the key authors and journals in the study domain. The broad topics addressed during the literature review were construction disputes and ADR methods in the construction industry. The review was further extended to research methodology-specially relating to quantitative research.

Accordingly, literature review was carried out to fulfil the aim of the research. First, it identified the various aspects related to arbitration and other different methods. Further, it compared and contrasted the advantages and disadvantages of the arbitration in order to analyse the current practice to overcome the problems in arbitration. When compared with litigation, arbitration method has several advantages and it was necessary to develop arbitration method to suit the nature and the requirement of the industry.

The data collected from the detail questionnaire survey was analysed on one to five Likert scale, less important to most important. Respondent's data was based on a statistical analysis tool such as Mean weighted Average, Kendall's Coefficient of Concordance and Coefficient of Variation (CV).

6.1. RESPONDENT AND EXPERIENCE

25 Questionnaires were distributed among leading experienced professionals in the construction industry. 18 questionnaires were received. Figure 1 and 2 shows the details of respondents

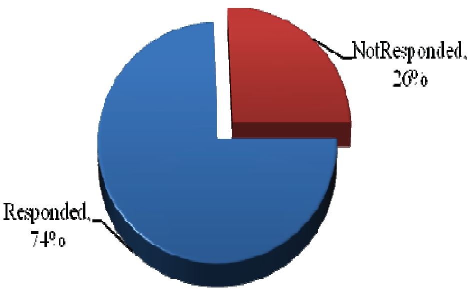

Figure 1: Rate of Respondents

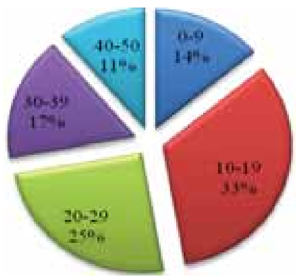

Figure.2: Years of Experience of Respondents

6.2. *General Consideration of Arbitration*

According to analysis of data, ADR methods were ranked in Table 1 and it is considering mean rating of their effectiveness in the present practice.

Table 1: Ranked ADR Methods Based on their Effectiveness

ADR Method	Mean of Rating	Rank
Negotiation	1.35	**1**
Adjudication	2.18	**2**
Mediation	2.46	**3**
Arbitration	3.82	**4**

Arbitration got the 4th place of ranking, however, that should prevail as an ADR method in order to settle disputes which have complex scope and to avoid courts for those kinds of disputes. Also, many professionals who have got more experiences on construction industry showed a clear understanding of the present arbitration practice.

6.3. *Identification of Advantages of Arbitration*

Within the identified nine advantages, the mean level of satisfactions of eight advantages were over 3.00 out of five point Likert scale. These advantages were ranked based on the mean weighted rating worked out by the questionnaire survey as shown in the table 2. The CV of each and every factor were calculated and included in the Table 2. CV of first eight factors were below 40% which can be considered as low CV, even the CV of ninth factor is 42.41%. Thus, it was ensured that the consistency of data set is within an accepted level.

Table .2: Ranked Advantages of Arbitration

Statement	Mean Rating	% CV	Rank
Expertise can be involved as Arbitrators	4.38	18.29%	**1**
Confidentiality	4.26	17.29%	**2**
Party autonomy	4.17	24.68%	**3**
Finality and reliably enforced(Enforceability)	3.68	25.17%	**4**
Less formal and simple	3.47	35.47%	**5**
Flexibility of procedure	3.31	36.16%	**6**
Expeditious	3.28	33.14%	**7**
Fair and genuinely neutral decision	3.18	29.78%	**8**
Inexpensive method	2.82	42.41%	**9**

6.3.1. *Discussion of Advantages of Arbitrations*

Advantages of arbitration, ranked above were descriptively analysed in order to create broad scope using above results. Parties have the autonomy to select their arbitration panel, procedure and the venue which will save the time and money. Arbitration will take place only in the presence of parties involved and the panel. The whole process of arbitration has flexibility to change according to the necessity of the parties. Whereas Litigation has rigid process and they are not flexible and cannot change considering characteristics of the disputes.

6.4. *DRAWBACKS OF ARBITRATION*

Within the identified twelve disadvantages, the mean level dissatisfaction of eleven disadvantages was over 3.00 out of five point Likert scale. These disadvantages were ranked based on the mean weighted rating worked out by the questionnaire survey as shown in the table 3. CV of 9 factors were below 35% which can be considered as low CV. Thus, from that it is ensured that the consistency of data set is within an accepted level.

Table 3: Ranked Drawbacks of Arbitration

Statement	**Mean Rating**	**CV %**	**Rank**
Higher involvement of lawyers	3.86	26.38%	**1**
Less concentration on Technical Issues	3.81	24.98%	**2**
Delaying of arbitral award	3.67	31.27%	**3**
Same procedure apply for settlement of all disputes	3.64	32.28%	**4**
High fees/of the arbitrators	3.61	30.54%	**5**
Weak tribunal	3.33	30.43%	**6**
Similar to court procedure	3.28	35.44%	**7**
Different arbitrators will find dramatically different resolutions	3.19	24.61%	**8**
Unawareness of the method	3.14	35.84%	**9**
Arbitration cannot easily conduct multi party disputes	3.08	32.32%	**10**
Limited jurisdiction	3.00	39.04%	**11**
Challenge to award	2.83	28.61%	**12**

The drawbacks discussed above were descriptively analysed using the same methodology as in advantages. The fees (compensation) of arbitrators and the cost of other facilities such as venue, documents have to be borne by the parties. If the case is dragged for several months the cost would increase even than litigation. There are limited numbers of technically qualified arbitrators in Sri Lanka. Therefore some arbitrators cannot control the construction proceedings. Parties have great autonomy to control procedure and select arbitrators; however in practice they do not use this opportunity to increase the effectiveness of the arbitration. Unawareness of professionals and parties involve in the construction industry are major problem for better practice of arbitration.

In construction industry employers, contractors, sub-contractors and other parties are involved in disputes due to different reasons. Arbitration has a somewhat rigid procedure than other ADR methods which make difficult to handle multiparty disputes. On many occasions the power of arbitrators is limited which is given by the Act. Therefore in Sri Lanka, summons, interim measures etc should be enforced by the Commercial High Court. It affects independence of the arbitrators and further it increases the involvement of litigation.

7. SUGGESTIONS FOR DEVELOPMENT OF ARBITRATION

Suggestions were ranked based on the mean weighted rating worked out by the questionnaire survey as shown in the Table 4. Even the highest CV is 41.06%. Thus, it is ensured that the consistency of data set is within an accepted level.

Table 4: Ranked Suggestions for Development of Arbitration

Statement	Mean Rating	CV %	Rank
Adopting of qualified arbitrators	4.56	15.25%	**1**
Changing of attitude of professionals	4.19	22.67%	**2**
Conducting awareness programmes	4.11	24.52%	**3**
Involvement of experts from the construction industry as arbitrators	4.06	21.21%	**4**
Introduction of recommended arbitration Clause / Agreement	3.89	26.64%	**5**
Introduce Construction Industry (model) arbitration rules	3.81	23.35%	**6**
Establishment of statutory construction arbitration	3.64	34.23%	**7**
Use inexpensive conference Rooms/venues	3.06	37.47%	**8**
Conduct the arbitration a full day basis	2.86	41.06%	**9**

The suggestions which were ranked above were descriptively analysed in order to create broad scope of them. Accordingly, parties should select qualified arbitrators considering the nature of the dispute. The most appropriate composition of the arbitral tribunal should consist of two technically qualified arbitrators and one Lawyer or retired Judge as the chairman. Experienced professionals in the industry should conduct awareness programme to the other professionals who are involved in the construction arbitration. Further, the awareness should focus on changing attitude of professionals on arbitration and promote the correct practice of arbitration as ADR method. Professionals involved in the construction have the knowledge and suitable background to give the most suitable and fair awards for disputes. Thus engineers, quantity surveyors and architects should enhance their knowledge on arbitration and increase the effectiveness of the method.

FIDIC Conditions of Contact and ICTAD-SBD forms of contracts provide arbitration clauses. However, it should be described more than that in the conditions of contract in construction contracts in order to understand easily. Therefore, qualified arbitrators or experienced professionals should draft and publish comprehensive arbitration agreement. Further, they should prepare model arbitration rules and guidelines for the parties and arbitrators who wish to use construction arbitration as a dispute resolution method. Also facilities for arbitration hearing should be provided outside Colombo.

8. CONCLUSIONS AND RECOMMENDATIONS

Disputes are considered to be inevitable in construction industry. First, it identified the process of arbitration. After that, it explored the arbitration process which is practiced in the Sri Lankan construction industry. Further, it was compared and contrasted the advantages and disadvantages of the arbitration in order to analyse the capability and the understanding of current practice to overcome the problems in arbitration. The identified issues in the process of arbitration and the suggested solutions for the success of arbitration practice in construction industry have been discussed. The study has identified the current arbitration practice in construction industry and introduced suggestions to increase the effectiveness of arbitration. The professionals involved in the construction industry have the responsibility to increase the effectiveness of the arbitration. Appointment of a Lawyer, Architect and an Engineer to the Arbitral tribunal may be very appropriate. Government should promote the current centres that carry out arbitrations in Sri-Lanka as well as help in the formation of an Institute of Dispute Resolution Management to settlement of disputes and educate and train professionals in the field of arbitration.

Followings are some further recommendations suggested to the authorities in the Sri-Lanka construction industry.

- Involvement of experts from construction industry as arbitrators

- Adopt Construction Industry Arbitration (Model) Rules
- Use inexpensive Conference Rooms
- Change the attitude of professionals
- Establishment of Society of Construction Arbitrators Society of Construction Law
- Introduce Recommended Arbitration Clause / Agreement
- Conducting of Awareness programmes

Arbitration is a voluntary procedure available as an alternative dispute resolution method to litigation. The professionals involve in the industry have the responsibility to increase the effectiveness of the construction arbitration. Disputes resolved by arbitration will no doubt be beneficial to the country. The construction arbitrator needs to possess a strong personality in displaying humility, empathy and understanding for the burdens that the disputing parties have to bear. Accordingly, professionals should increase the effectiveness of arbitration process in construction industry of Sri Lanka.

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10. END NOTES

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STAKEHOLDERS' PREFERENCE TOWARDS THE USE OF CONFLICT MANAGEMENT STYLES IN DUAL CONCERN THEORY IN POST CONTRACT STAGE

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ABSTRACT

The tendency of having conflicts is extremely high in construction industry due to the complexity in relations, lengthy process and multidisciplinary involvement. It can be seen that conflicts in post contract stage have more tendency to increase due to number of reasons. Even though the industry uses conflict management styles, still there is no sign of decreasing conflicts which are subsequently converting into disputes. Therefore, the requirement of conflict management should receive a prior consideration. Construction professionals commonly use dual concern theory as their conflict management style. However, they are incapable of using this management style effectively according to the conflict situation so that the amount of conflicts is rising. This creates a current issue of minimizing conflicts by effective management because it directly affects the project success. Since conflicts disturb the proper coordination and corporation of human resource and cause project delays, effective conflict management in construction projects leads the project towards the sustainable construction practice by creating a proper coordination between all relevant parties and eliminate unnecessary project delays caused by conflict environment. Accordingly, the aim of this study is to identify the stakeholder preference towards the conflict management styles in Dual Concern Theory in post contract stage. A comprehensive literature review and an interview from selected case studies were conducted to collect data. The findings of this study prove that having a proper conflict management can achieve sustainable construction practices such as using human resource efficiently, willingness to work and effective time management.

Keywords: *Conflict; Construction Industry; Conflict Management; Dual Concern Theory; Post Contract Period.*

1. INTRODUCTION

Construction industry can be identified as one of the fundamental industries which are essential for the development of any nation since the physical development of construction projects such as buildings, roads, and bridges is one of the measures of the economic growth all over the world (Alzahrani and Emsley, 2012). It deals with the complexity of construction by decomposing the whole project into several sub projects, which are let or sublet to several general contractors and subcontractors (Chua and Song, 2003). Due to the complexity in relations, lengthy process of construction and multidisciplinary involvement in the construction project, the tendency of having conflicts is extremely high (Jaffar *et al.*, 2011). Conflict can be managed, possibly to the extent of preventing a dispute resulting from the conflict (Fenn, Lowe and Speck, 1997). According to Popovic and Hocenski (2009), conflicts cannot be eliminated. They only can be managed in such a way that they never developed and become a disturbance to the project success. According to many writers, Dual Concern Theory is one of the most commonly used conflict management styles all over the world. The theory argues that conflict management can be effectively done by considering the behaviour; as a meaning of high or low concern for self, combined with high or low concern for others (Chou and Yeh, 2007).When consider deeply about conflict management, it can be understood that well managed conflicts lead to sustainable construction practice. Here, sustainability can be described as preserving the human resource (professionals) for future generation while effectively taking their service at

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present. In order to preserve the professionals, it is important to increase their willingness to work by mitigating frustration. The basic source of frustration is having conflicts therefore, by having proper conflict management, frustration can be mitigated. Ultimately, managing conflicts will preserve the human resource to the future.The aim of this study is to identifythe stakeholders' preferencetowards the conflict management styles in dual concern theory in post contract stage. This paper initially provides a comprehensive literature review in order to identify the prevailing knowledge about the conflict management in post contract period and application of dual concern theory. Then the findings of three case studies are presented and further subjected to a discussion. Finally, conclusions are drawn from the findings.

2. CONFLICT MANAGEMENT

2.1 WHAT IS A CONFLICT?

Fisher (2000) defined conflict "as an incompatibility of goals or values between two or more parties in a relationship, combined with attempts to control each other and antagonistic feelings towards each other". A recent study by Popovic and Hocenski (2009) on the Conflict Management defined a conflict as a struggle or contest between people with contrasting needs, ideas, attitudes, values, or goals. Therefore, a conflict can be defined as a situation where two or more parties in a relationship have incompatible approach towards a common goal. According to Acharya *et al.* (2006), there would be no conflicts in a perfect construction world but there is no such perfect construction world in the real context. Therefore, conflicts are inevitable. Fisher (2000) stated that nonexistence of conflicts usually signal the absence of meaningful interaction. Therefore, having conflicts leads the project into success. But the success can be only achieved through proper management of conflicts.

2.2 TYPES OF CONFLICTS AND THEIR SOURCES

Many types of conflicts can be seen in construction industry. Acharya *et al*. (2006) have listed various types of conflicts that can be taken place in construction project along with their sources. They have categorized the conflicts into five major categories based on the parties involved in the construction project. They are, owner evoked conflicts, consultant evoked conflicts, contractor evoked conflicts, third parties evoked conflicts, and other project matter evoked conflicts. They further explained the sources of aforementioned conflicts.Confusing requirements of owner, excessive change orders, supremacy of owner/consultant, errors and omissions in design, non-payment to subcontractors, conflicts in documents, lack of communication and union strikes are some of those sources which can be commonly seen in any construction project.

Similarly, Fisher (2000) pointed out five major conflict types that can be commonly seen in the industry based on the nature of the conflicts once it has been examined from outside of the conflict situation.They are interpersonal conflicts, role conflicts, intergroup conflicts, multi party conflicts and international conflicts. Interpersonal conflicts occur when two people in the construction project have incompatible needs, goals, or approaches either in their personal relationship as well as professional relationship. The major source for this kind of conflicts is poor communication. Role conflicts occur with having real differences in role definitions, expectations or unclear boundaries of responsibilities between individuals who are interdependent. The sources for this type of conflicts are poor communication, lack of information, documentation errors and delegation of power. Intergroup conflicts occur between parties involved in the construction. There are many sources for this type of conflicts such as design errors, documentation errors, delays, non payments, differences in attitudes and variations. Multi party conflicts occur between two or more parties. It can be happened between direct stakeholders and indirect stakeholders as well as between the project and the outside parties. The major sources for this type of conflict are environmental hazards, land acquisition, improper garbage disposal and pollution. Sometimes, a construction project can be a threat to another country or even to the whole world. Then international conflicts can be seen. According to Thalgodapitiya (2010), the causes of construction conflicts have numerous reasons including unrealistic expectations, change of scope, differing site conditions, delays, poor workmanship/quality, adverse weather, and many others. He further explained that the people factors have the biggest impact on project dispute potential, while the process and project attributes have important but less influential impact respectively.

2.3 Effects of Conflicts

Tjosvold (2006) argued that conflicts are not always destructive. They can be constructive as well if they are well managed. He further stated that neither conflicts just happen nor escalate by itself. It is people who involve in the conflict situation make choices which escalate conflict or lead to more constructive outcomes. Similarly Popovic and Hocenski (2009) explained that conflicts can provide beneficial results. Deutsch and Coleman (2000; as cited in Fisher, 2000) stated that the way in which conflict is handled decides whether the ultimate result be constructive or destructive. Therefore, it can be said that constructive conflicts provide food for thought to the professionals and derive creative solutions and enhance the project success whereas destructive conflicts create complicated situations which weaken the stability of project progress. However, the ultimate result of unmanaged conflicts will be disputes which require expensive dispute resolution with lot of wastage of time, money and energy. Third party has to be involved in the process of dispute resolution and he has to be paid. In addition, considerable time have to be spent for the dispute resolution procedure so that it will consume the time allocated for construction. By the end of the dispute resolution, all related parties will be frustrated and tired. This will decrease their efficiency and willingness to work. Yiu and Cheung (2005) explained that if the level of conflicts escalates continuously, it may become psychological struggles between the contracting parties and manifests as disputes and the unfortunate outcomes will be loss of productivity and increase in cost of construction.

Conflicts can be managed, without allowing it to escalate into a severe stage and become a dispute (Fenn, *et al.,* 1997). If the conflicts escalate into their severe stage (disputes), it will be ended up with costly litigation (Adnan *et al.*, 2011). According to Thalgodapitiya (2010), it is visible that disputes generate a considerable damage to a construction project. He further said that litigation in construction industry is continuously increasing in the past few decades due to various factors. Since time, money and energy are so precious for the project, they cannot be wasted. Therefore, managing construction conflicts is essential for the successful completion of the project. Fisher (2000) determined that escalation of conflicts make them more difficult to manage. According to him due to the fear of one party towards the others and defensiveness will feed the conflict and lead it to quick escalation. Friedman *et al.* (2000) stated that conflicts will shape the employee's social environment, stress and relationship with others. According to Adnan *et al.* (2011) conflicts may occur several serious effects such as delays in development of the project, reduction of requirements due to unavailability of enough time, reduces performance of employees and broken professional relationships.

2.4 What is Conflict Management?

Generally, management can be defined as "the process of dealing with or controlling things or people" (Oxford Dictionary, 2013). Therefore, conflict management can be defined as the process of dealing with or controlling conflicts. According to Popovic and Hocenski (2009), Conflict management is the principle that all conflicts cannot be resolved, but learning how to manage conflicts can decrease the destruction they occur. Ozkalp *et al.* (2009) described that conflict management is more important than conflict resolution because in practical context, conflicts are hard to resolve but can manage by using a proper strategy. On the other hand, Leung *et al.* (2005) stated that different dimensions of conflict resolution have to be identified in order to manage the conflict well in the complicated construction industry.

3. Conflict Management in Post Contract Stage

Post contract stage can be identified as the time period which starts from the commencement of construction to handing over the project to the owner. The stakeholders who involve in this stage are contractors (main contractor and sub contactors), sponsors, owner group, design and supervision consultant team, suppliers and agents, and labour force. In post contract period, many professionals and parties are involved in the construction that have their own values, beliefs, interests, education and needs. Therefore, the tendency of having conflicts is more when compared to pre contract period. According to Kumaraswamy (1998), conflicts are arising because of the involvement of more stakeholders with different cultures, disciplines and diverse objectives which can be highly seen in post contract stage. Since the design is continuously changing due to reasons such as impracticability, design errors and changes in client's requirements, the conflicts that can be seen in the pre contract period probably can be seen in the post contract stage (Ng and Skitmore, 2000). Therefore, it is very important to have a clear idea about the effective management of those conflicts in post contract stage because they directly provide bad effects to the project success (Awakul and Ogunlana, 2002).

4. DUAL CONCERN THEORY

The dual concern theory, proposed by Pruitt and Rubin (1986), is the most often cited theory in conflict management literature (Chou and Yeh, 2007). However, according to Friedman *et al.* (2000), the conceptual foundation of Dual Concern Theory was laid by Blake and Mouton's (1964). The dual concern theory argues that conflict management can be effectively done by considering the behaviour; as a meaning of high or low concern for self, combined with high or low concern for others (Chou and Yeh, 2007). The Oxford dictionary (2013) defines effectiveness as "the degree to which something is successful in producing a desired result". According to Popovic and Hocenski (2009), the principle of conflict management is not working for eliminating of conflicts but learning how to manage them and decrease the odds of non-productive escalation. Therefore, effective usage of conflict management styles in dual concern theory means that the degree to which it is successfully used to control and decrease conflicts in such a way that they never become a disturbance to the project success. According to Chou and Yeh (2007), there are five conflict management styles in dual concern theory. They are problem solving style, obliging style, forcing style, avoiding style and compromising style.

4.1 PROBLEM SOLVING STYLE

Both Friedman *et al.* (2000) and Cheung and Chuah (1999) identified this style as collaborating or integrating style. If further described, usage of this style for conflict management will lead to high concern for both self and others. Fisher (2000) recognized this method as a win-win approach. According to him, this enables to achieve the goals of all parties who are in the middle of a conflict situation since they accept the conflict as a problem that should be solved together rather than winning a war against each other.

4.2 OBLIGING STYLE

Chou and Yeh (2007) described this style as having high concern for others and low concern for self. If further describe, this style is used when there is a situation where one party technically knows that the other party is more reasonable and fair even though they have an interest in some other solution. Therefore, they accept and incorporate the desires of the other party. It can be said that this style is used when one party has more experience, power and good reputation than the other party.

4.3 FORCING STYLE

According to Chou and Yeh (2007), this style determines the high concern for self and low concern for others. This can be often seen within the construction industry due to the desire of exhibiting power over the others. If the intention of using this style is merely showing the power, dominance and aggression, it will not effectively manage the conflict situation. Instead, it will destroy some important professional relationships between construction stakeholders. Fisher (2000) described that this style can be used with the means of socially accepted mechanisms such as majority vote, authority of the leader or determination of judge whereas it can be also used with the aggressive mechanisms such as secret strategies or threats. However, there are conflict situations in which there is a need of using this style such as labour handling, handling strikes of staff and managing construction teams due to the fact that people obey the instructions rather than consider about requests.

4.4 AVOIDING STYLE

Chou and Yeh (2007) identified this style as having low concern for both self and others. This is also called withdrawal or denial style. This can be a win-win approach only if used for correct conflict situations but it is very important to notice that avoiding a conflict often leads to the development of that particular conflict into a dispute where dispute resolution is required. The consequences will be unnecessary cost and wastage of time by having expensive alternative dispute resolution techniques. According to Fisher (2000), this style is a win-win approach where the conflicting parties see the situation as we (both parties) against the conflict rather than being against each other. This style can be often used where there are interpersonal conflicts which do not directly related to the construction project.

4.5 COMPROMISING STYLE

Above mention styles are the basic conflict management styles in dual concern theory. However, authors recently introduced another style called compromising style. Cheung and Chuah (1999) identified this style as a procedure where both conflicting parties agree on acceptable solutions in which they have some degree of satisfaction. In addition, this style relates to the give and take attitude. The difference between compromising style and obliging style according to Cheung and Chuah (1999) is that the conflicting parties go for the simplest compromise in the obliging style whereas in compromising style there is a deep consideration about the concessions. Furthermore, Friedman *et al*. (2000) stated that this style describes the moderate concern for self and other.

5. RESEARCH METHOD

The approach undertaken for this research comprised of two components, a literature review and a data collection from case studies. A comprehensive literature survey was carried out through journals, books, articles, reports, government publications, dissertations, previous research investigations and internet to identify the basic facts and the theories already subjected to discussion about conflict management and Dual Concern Theory.Case study research method was used to conduct an in-depth study about the current status of conflict management in the Construction Industry. Three cases were selected and they were examined by conducting semi-structured face to face interviews with selected partiesto identify the weaknesses of prevailing conflict management systems in post contract stage and the applicability of Dual Concern Theory for conflict management. Collected data was analysed using a content analysis.

5.1 PROFILE OF THE CASES

The first selected case study (case study 1) was construction of an administrative complex building which is recently completed successfully. This project was initially planned to do within 24 months but extended up to 35 months due to major variations. The client was one of the ministries of government and the contractual arrangement was with ten specialized contractors and three subcontractors.Therefore, the number of parties involved is very much high when compared to other projects. It was a measure and pay contract which had BOI (Board of Investment) facilities.The proposed construction was a large building which had identical 12 floors, a basement, a ground floor and the upper floor for machinery. Consultant was semi government organization whereas all specialized contractors and subcontractors were private organizations. Overall relationship between client and specialized contractors seemed to be better than the relationship between consultant and contractor and client and consultant.

The second case study (case study 2) is an ongoing road project. Estimated duration for this project is 2 years. The client is a regulatory body of the government and the contractual arrangement of this project is with one main contractor and one subcontractor. It was planned to handover the completed sections as soon as the construction is finished. The measure and pay procurement method is used. Even though it is a government project, BOI facilities are not received.The project carries out of an improvement and rehabilitation of a type B road. Consultancy is done by the project consultancy unit of the client organization whereas both main contractor and sub contractor are private organizations. The relationship between client and contractor seemed to be average due to the supremacy of the client. Since the consultancy is done by the client organization, their relationship tends to be good but strictly official. However, the relationship between consultant and contractor seems to be better when compared to aforementioned two relationships.

Third case study (case study 3) is an ongoing apartment building construction. This project is planned to complete within two years. The client is a private company and the contractual arrangement is with one main contractor and three subcontractors. Currently, the construction is successfully continuing with some minor time extensions. Measure and pay procurement method is used. The proposed apartment building is consisting of 25 floors which have minor differences with each other. Client is providing few major construction materials to the contractor. The overall relationship between client and contractor seems to be official but friendly. The relationship between client and consultant is very friendly and comfortable. However, the relationship between consultant and contractor is strictly official due to the supremacy of the consultant.

6. DATA ANALYSIS

The findings from semi structured interviews with the selected stakeholders of selected case studies are summarized in Table 1. The types of conflicts that can be commonly seen in each case study are listed along with their sources, conflict management style used and the degree to which they were succeeded. According to the table 1, it is identified that disagreement in scope change, cost of variations, delays, sharing the cost of delays, quality issues, progress issues, interim payment issues, conflicts between labourers, conflicts between staff members and documentation errors are the most common conflicttypes that can be seen in the construction industry. However, their sources can be different from one project to another. It can be seen that all three projects have used dual concern theory for conflict management even though they are not aware of doing so. Based on the facts that collected from the case studies, it was identified that majority of professionals in the construction industry are not aware about dual concern theory but they use it in conflict management. The problem is that majority of the construction industry are unaware of using the correct conflict management style in correct conflict situation. One professional from case study 1 (Respondent 1) said that "*even though we know that we have to manage a particular conflict, most of the time we are not sure what should be the correct conflict management style which can be used. Therefore, we often go for negotiation. But there were several times we could not manage the conflict properly by negotiating*". Another professional said "*I think problem solving by negotiating is not the only technique that we can use to manage a conflict situation but it is the only technique we practically use in the project because we are not sure when we can use the other styles. Only problem solving style is used in our project*".

Table 1 consists of the average ranking given by selected professionals to the selected conflict management style used to manage each conflict. According to them, the degree of successful management of the conflict is ranged from 1 (very low) to 5 (very high). It can be seen that almost all the conflicts mentioned in the table 1 are successfully solved but according to the opinion of the interviewed professionals, even though the conflict is well managed, it rarely provides satisfaction to all conflicting parties. Therefore, frustration and not willing to work can be often seen in the professionals and other parties. All professionals agreed that the best way of managing the conflicts is using the management styles in dual concern theory. Therefore, there is no doubt that the problem of escalating conflicts is due to the weaknesses of the theory. The problem lies with the usage of correct conflict management style in correct conflicting situation.

According to Table 1, it can be seen that all 3 case studies have common conflicts such as interim payment issues, progress issues, conflicts between labourers and conflicts between staff members. Furthermore, Table 1 clearly demonstrates that the aforementioned common conflicts were often managed using the same conflict management style. However, in several situations it was different from one case to another. According to the findings, the ultimate degree of succession was occasionally different even though the same conflict management style was used. For example, both case study 1 and case study 2 have used problem solving style for managing the conflicts between labourers. But, case study 1 has succeeded more than the case study 2. In addition, case study 1 and case study 3 have used avoiding style for managing conflicts between staff members but case study 3 succeeded more than case study 2. Therefore, it can be assumed that, even though a particular conflict management style is used for a particular conflict, the degree of effective management of the aforementioned conflict can be changed from one project to another. An interviewee of case study 1 (Respondent 2) stated that "*I can't say that a particular style is the best management style for a particular conflict because it can change according to the attitudes of people who related to the conflict as well as the nature of project"*. Similarly, another interviewee from case study 3 (Respondent 3) pointed out that "I'm sure we can't label the correct management style for each and every conflict because there is no such correct one". Therefore, it can be concluded that the change in degree of success can be happened due to the attitudes, interests, education status, needs and nature of the professionals. In addition, it has an effect from the working environment and the nature of source by which the conflict is created.

According to table 1, it can be seen that using different styles for a particular conflict will change the degree of successful management. For example, case study 2 used obliging style to manage the interim payment issues whereas case study 2 used compromising style and case study 3 used forcing style. However, the Table 1 demonstrates that obliging style has low degree of succession while compromising style has very high degree. An interviewee from case study 2 (Respondent 4) stated that "*sometimes we can define a particular conflict management style as the best for a particular conflict due to its nature. For example, interim payment issues are common in every construction project. The only way of managing it is compromising. We neither can force the other party to accept our interests nor accept what other party say by keeping away our own objectives. It is obvious that we can't avoid the conflict because it's greatly related to the construction. I don't think we can use problem solving style because this conflict can never manage by giving full satisfaction to both parties. It's the nature of this conflict. So, the only way of managing it is by using compromising style*". Therefore, it can be assumed that even though the nature of projects and the professionals are different from one case to another, a particular conflict management style can be the perfect style for a particular conflict due to its unique nature.

Respondent 1 mentioned that once they have to go for alternative dispute resolution due to errors in documentation. He said that "*once we had to deal with a problem regarding an error in the BOQ. What we did was having number of meetings to discuss the matter but it never solved because neither of parties were ready to compromise or give chance to the other party. Both parties were in the opinion that they are correct. There were strong arguments between several professionals and the good relationship between them was broken. Therefore we had to go for a mediation process because both parties didn't want an expensive and time consuming arbitration process. However, it was resolved but it took so much time and money and remained broken professional relationships and frustration*". According to respondent 1, the dispute derives from an unmanaged conflict between the Quantity Surveyors of both parties. They have continuously used problem solving style to manage the conflict but it wasn't effectively managed. Because of that they have to go for a dispute resolution method. According to respondent 1, the conflict was not effectively managed because they have selected the wrong conflict management style. He further stated that ultimately both parties realized that if they used compromising style, they would have effectively manage the conflict without letting it to escalate and become an expensive dispute because the ultimate solution they got from the dispute resolution is compromising with other party. This will clearly shows that using correct management style is the key for effective conflict management.

From the opinions taken from the professionals, it is highlighted that majority of them are interested in problem solving style and compromising style. An interviewee from case study 2 (respondent 4) mentioned that "*we always go for problem solving style or compromising style because they make us discuss about the conflict in a friendly manner. We don't want to destroy the good relationship we have with all other parties because in my opinion, good and strong professional relationships are the key to project success*". Several interviewees from case study 1 said that "*negotiation is the only method we practically use in our project. Everyone accepts this method*". According to them, compromising and problem solving styles can be applied in most situations. An interviewee from case study 3 (respondent 5) stated that "*I think there are situations in which we have to let other party win because sometimes our desires will not tally with the objectives of the project. When the conflict arises and when we hear the other party's reasoning, automatically we come to know that they are more reasonable. Then what we should do is keep our desires aside and make their desires ours. But when it comes to conflicts regarding labour handling and conflicts related to labour, the best way of managing them is using forcing style*". According to him, both forcing and obliging styles should be used when any party realizes that the other party is more reasonable and fair.

Avoiding style is the best for personal conflicts if they are not directly related to the success of the project. Most of the interviewees said that "*we never care about the personal conflicts between employees as long as they become a problem to the project. Most situations, they are not becoming problems to the project*". Many professionals agreed that using problem solving style for personal conflicts which are not affecting the project success will only escalate the conflict and make a subsequent effect to the project. This will happen when a third party is trying to involve in the conflict.

Few professionals stated that forcing is the best style because it made the conflict managed automatically and quickly. But majority of professionals determined that forcing is the last style that should be used for a conflict situation because it makes the related parties frustrated. But they agreed that it can be useful in some situations rather than any other style. All professionals declared that it is important to establish a proper method for conflict management in every construction project and to pay a special attention for conflict management. Respondent 1 said that "*we all need a proper education about conflict management and every project should have more consideration about conflict management because it can even terminate a contract*". The proposal of the interviewees is to use all the styles in dual concern theory appropriately according to the conflict situation. They further stated that it is very useful if professionals are given a proper knowledge about conflict management.

From the evaluation of case studies, it can be identified that the magnitude of project is not proportionate to the amount of conflicts. According to table 1, case study 1 is having more conflicts even though case study 3 is the biggest project. Moreover, it can be concluded that the amount of conflicts have no relationship with the magnitude of the construction project. However, it has a relationship with duration of the project. Respondent 3 stated that "*when the duration of project is high, the tendency of having conflicts is high due to more and more interaction of parties and urge to see an end of their monotony life. Receiving time extension can be considered as asking for more and more conflicts*". Similarly, the project type has a relationship to having conflicts. According to table 1, building projects have more tendency to generate conflicts rather than civil projects due to their complexity. However, when compare two building types (case study 1 and 3), it can be revealed that there is no relationship between building type and conflicts. Nevertheless, the complexity in construction of buildings can cause more conflicts. Furthermore, amount of conflicts is proportionate to the number of parties involved. It can be clearly seen in table 1. Case study 1 has more conflicts due to the presence of number of specialized contractors and subcontractors. Moreover, the most commonly used styles were problem solving and compromising even though they were not appropriate insome situations.

It is obvious that proper conflict management is a sustainable construction practice. The word sustainability can be described as a situation where it meets the need of the present without limiting or eliminating the ability of future generation to meet their needs. Normally, stakeholders (professionals) of the industry are human resources and frustration and poor coordination due to conflicts will diminish their willingness to work in the future. So, it can be said that conflicts will limit the ability of future generation to meet their need of having the service of professionals. Therefore, managing conflicts will preserve the human resource to the future. Apart from that, by not having a conflicting environment will lead to proper documentation and record keeping and it will be a preservation of knowledge for future generation while using it in the present.

Table 1: Conflict Management in Selected Projects

Case Study	**Conflicts Occurred**	**Sources of Conflicts**	**Conflict Management Style Used**	**Degree of Success**				
				1	**2**	**3**	**4**	**5**
1	• Disagreement in scope change • Cost of variations • Delays • Sharing the cost of delays • Delayed claims • Cash flow discrepancies • Quality issues • Progress issues • Interim payment issues • Conflicts between labourers • Conflicts between staff members • Documentation errors	• Confusing requirements of owner • Design errors • Variations, Adverse weather • Lack of pre-determined conditions • Excessive work load, negligence • Poor documentation • Not following the specifications • Labour idling, poor coordination • Poor data recording • Poor communication and differences in attitudes and mentality • Lack of information, negligence, human errors	• Forcing • Compromising • Problem solving • Compromising • Compromising • Problem solving • Forcing • Compromising • Obliging • Problem solving • Avoiding • Problem solving		✓	✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓
2	• Cost of variations • Conflicts between labourers • Interim payment issues • Progress issues • Quality issues	• Lack of information during design stage • Poor communication and differences in attitudes and mentality • Poor coordination, adverse weather • Negligence of the contractor, Not following the specifications	• Problem solving • Problem solving • Compromising • Compromising • Forcing			✓	✓	✓ ✓ ✓
3	• Interim payment issues • Progress issues • Conflicts between labourers • Conflicts between staff members	• Supremacy of the consultant • Ineffective labour management • Poor communication and differences in attitudes and mentality	• Forcing • Problem solving • Avoiding • Avoiding			✓	✓ ✓ ✓	

7. DISCUSSION

Acharya *et al*. (2006) stated that conflicts are inevitable in construction industry. Since the results of conflicts cannot be predetermined, there is a tendency of escalating the conflict and leads to non-productive results as well as beneficially results (Popovic and Hocenski, 2009). Similarly, findings of case studies confirm that conflicts are inevitable and they should be managed in such a way that they do not escalate in destructive manner. According to the case study findings, it is important to consider about destructive conflicts rather than productive conflicts since they disturb the successful completion of the construction project. According to the literature review it is clear that dual concern theory is the most common conflict management style used in both local and international construction industry. In addition, the literature review discusses about the conflict management styles in dual concern theory in a descriptive manner providing examples for how they have been used to manage the conflicts. However, there is no clear explanation about identifying the most appropriate conflict management style for a particular conflict situation. Similarly, the findings from case studies clearly show that construction professionals are not aware of the right conflict management style for the right situation and this is the key problem to enhance the conflicts in most of the projects.

Cheung and Chuah (1999) described the problem solving style as the conflict management style which provides the best solution to the conflict even though there is a need of modifying or discarding the original views of one or both parties. Therefore, this style can be identified as a mean of problem solving through collaboration. Chou and Yeh (2007) explained the compromising style as having concern about matching others' concessions, making conditional promises and threats. Therefore compromising style provides partial satisfaction to both parties in equal measure. Similarly, the findings from the case studies prove that problem solving and compromising styles are more preferable because they are done in the form of negotiating which is the most famous method in any country. Even though there is no enough literature which confirms that problem solving and compromising are the best methods that can be used for conflict management the findings from case studies reveal that majority of construction professionals think they are the best methods in practical context. Fisher (2000) stated that forcing style is a win-lose approach where one party receives exactly what they want while other party is forced to accept the solution willingly or unwillingly by using the power. However, case study findings identify forcing style as a prestigious technique to use power over the subordinates. Further, findings reveal that forcing style cannot be used effectively without making one party frustrated thus it decreases the productivity of the employees.

When consider about the explanation of Chou and Yeh (2007), obliging style is a lose-win approach because only one party is able to have what was intended. The other party only gets an undesired but more reasonable solution to the conflict situation. However, this style can be identified as a conflict management style where all conflicting parties being flexible about having a solution. The case study findings provide a slightly different identification to the obliging style. The findings agree with the literature but it conveys a broader explanation. According to the findings not only obliging style is used when one party comes to know that the other party is more reasonable, but it is also used when one party has more control over the project than the other party (ex: consultant and contractor) and when one party depends on the other party (ex: contractor and suppliers).According to Cheung and Chuah (1999), conflicting parties can use avoiding style if they wish to ignore the actual or potential conflict. However, case study findings determine that avoiding style is better for interpersonal conflicts which are not relevant to the construction project. Case study findings also reveal that if the particular interpersonal conflict creates any kind of disturbance to the project, it should be managed by using another style, most probably the problem solving style.

There is scarcity of literature that proves construction industry is now recognized as an industry which consists of sustainability in professional construction practice. But the findings of case studies clearly show that in order to label a construction project as sustainable, it should have sustainability in every manner. Therefore, having sustainable construction practice such as preserving professional service for future use is now become a significant requirement. According to the findings, the basic disturbance for preserving professionals for future while obtaining their maximum service in the present is making them unwilling to work. The cause for this is having conflicts. Therefore, it is important to manage conflicts effectively in order to gain sustainable construction practices to every project.

8. CONCLUSIONS

Conflicts are inevitable due to the complexity and the multi disciplinary involvement in the construction project. They cannot be eliminated from construction projects. Therefore, the only thing that can be done is managing conflict without allowing them to escalate and create destructive consequences. The severe stage of a conflict is a dispute which obviously becomes a disturbance to the project success. Having conflicts will destroy the good professional relationships and waste time, money and energy.Conflicts can be managed effectively by using the conflict management styles in dual concern theory. The foundation of the theory is having concern about self and other. There are different conflict management styles according to the degree of concern having towards self and others. Majority of the construction projects follow this theory without knowing the exact definition of the theory. Therefore, sometimes it will not be able to use it effectively. Problem solving style and compromising style are the most common conflict management styles that are using all over the world. But they are not matching for every conflict situation. Therefore, the style should be selected appropriately according to the situation.Conflict management leads the project into sustainable construction practise by avoiding the frustration of stakeholders. It enables to preserve human resource for the future use. Therefore, conflict management is having a vital importance in the construction industry.

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STRENGTHENING THE SAFETY CULTURE FOR ORGANIZATIONAL SUSTAINABILITY

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ABSTRACT

The term 'sustainable development' can be defined as satisfying the needs of the current generation, without jeopardizing the future generation's ability to meet their needs. In terms of organizations, a Sustainable organization concerns the original momentum of the business continuity of the organization. Occupational Safety and Health (OSH) in general plays a key role in supporting business activities and delivering economic prosperity for the organization. Thus, OSH becomes a necessity for organizational sustainability. Organisational culture is a concept often used to describe shared corporate values that affect and influence members' attitudes and behaviours. Safety culture is a sub-facet of organizational culture, which is thought to affect members' attitudes and behaviour in relation to an organisation's ongoing safety and health performance. This paper aims to investigate the factors that influence safety culture positively in order to support the sustainability of the organization. A literature synthesis on organizational sustainability, occupational safety and health, safety culture, definitions of safety culture, components of safety culture and way to strengthen a safety culture are presented. The research findings highlighted that a safety culture mainly comprises of three components, namely, attitudes-both individual and organizational, work environment of and OSH systems occupied. Further few factors that influence safety culture positively were distinguished as management commitment to OSH, employee involvement and empowerment, proper OSH systems and feedback mechanisms, and continuous monitoring of OSH systems.

Keywords: *Occupational Safety and Health, Safety Culture, Sustainable Organizations.*

1. INTRODUCTION

Today, many authors refer to the sustainability concept as ambiguous and subject to debate or controversy; even though, there is consensus that, in general, sustainability refers to the ability or capacity to endure (Broekhuis and Vos, 2003; Giannettia *et al.*, 2010; Geelsa, 2010). On the other hand, sustainability associated with the development concept, turns to be a new archetype of social, environmental, and economic development which has started to spread globally during the past decade (Brundtland, 1987). An 'organizational sustainability' concerns the original momentum of the business continuity. There by, 'sustainability' and 'sustainable development' has become a topic that continues to gain the attention of safety, health, and environmental (SHE) professionals (Taubitz, 2010). However, most organizations consider occupational safety to be a secondary concern. This may be due to the fact that safety is focused mainly on tactical issues of OSHA (Occupational Safety Health Administration) recordkeeping, accident reporting, personal protective equipment, and other elements that, while necessary, do not resonate as part of long-term strategic initiatives, but the contribution these 'tactical issues' bestow to maintain the environment of a organization sustainable is often been overlooked (Taubitz, 2010). Thus, lack of conversation on safety and health is evident when sustainability is discussed. 'Safety culture' is frequently identified as being fundamental to an organization's ability to manage safety-related aspects of its operations, successfully or otherwise (Glendon and Stanton, 2000). Cooper (1998) established that a safety culture has impact on an organization's quality, reliability, competitiveness and profitability. Thereby, the need to develop and promote a strong safety culture for sustainability of organizations is acknowledged.With that

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acknowledgement, the paper discusses on the link between occupational safety and health and organizational sustainability through the concept of 'safety culture'.

2. RESEARCH METHOD

A comprehensive literature review was carried out. A keyword search for sustainable organizations, occupational safety and health, and safety culture were used to search literature from various sources such as electronic library data base, journal articles, online journals, e-books, web sites and other publications. The findings of the literature review is structured and presented under appropriate sections.

3. ORGANIZATIONAL SUSTAINABILITY

Sustainable organizations are enduringly successful - yet not all successful organizations will endure or are sustainable (Chartered Quality Institute, 2011). Organizational sustainability means managing the 'triple bottom line'- including financial, social, and environmental risks, obligations and opportunities (Smith, 2010). Therefore, sustainable organizations are generally resilient and create economic value, healthy ecosystems and strong communities. Further, this nature of organizations survives over a long period, as they are intimately connected to healthy economic, social and environmental systems. As a result, the sustainability movement exhibits strong parallels to the safety health and ethical conduct movements of years past. Management of Occupational Safety and Health (OSH) in organizations has become a very complex multi-functional science within operations management and Total Quality Management (TQM). It focuses on a non-legalistic approach whereby the organisational culture fosters spontaneous OSH and a high quality of work life (Steenkamp and Schoor, 2012). Thus, it is apparent that OSH does play a role in attaining better quality working life and ultimately the organizational sustainability. Further, according to the Joint ILO/WHO Committee on Occupational Health in 1950, the main focus in OSH is on three different objectives (Coppee, 2011):

(i) the maintenance and promotion of workers' health and working capacity;

(ii) the improvement of working environment and work to become conducive to safety and health

(iii) development of work organizations and working cultures in a direction which supports health and safety at work and in doing so also promotes a positive social climate and smooth operation and may enhance productivity of the undertakings.

This has led to establish a relationship between sustainability and OSH. It suggests that in order to have a smooth and productive operational process, an organization should have a safe and healthy work environment. Hence, sustainability is supported and enhanced by OSH. The next section of this paper is thus devoted to discuss OSH.

4. OCCUPATIONAL SAFETY AND HEALTH (OSH)

Occupational health and safety encompasses the social, mental and physical well-being of workers that is the whole person (Alli, 2008). Thus, successful occupational health and safety 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.(ILO, 1996).The ultimate goal is an organisation aiming to improve its health and safety 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 (HSE, 1997). OSH systems are designed to identify and minimise risks at the workplace. The effectiveness of such systems also affects business performance, either in a negative way if these systems are cumbersome or bureaucratic, or positively if they are well designed and function effectively. To have a positive impact, OSH systems need to function smoothly, in tune with, rather than in contradiction to, the overall management of the company (EU-OSHA, 2012). Further, as identified in the literature, OSH contributes to organization performance by (Cooper, 1998; HSE, 1997)

- Supporting human resource development;
- Minimizing the financial losses which arise from avoidable unplanned events;
- Recognizing that accidents, ill health and incidents result from failings in management control and are not necessarily the fault of individual employees;
- Recognizing that the development of a culture supportive of health and safety is necessary to achieve adequate control over risks;
- Ensuring a systematic approach to the identification of risks and the allocation of resources to control them;
- Supporting quality initiatives aimed at continuous improvement.

Thus, safe and healthy workplaces help businesses and organizations to succeed and prosper, and also benefit wider society. Safety and health at work have traditionally been approached mainly by means of legislation and enforcement measures. He stated that there is enough evidence to indicate that an effective safety culture is an essential element of any business strategy, as it has so many positive effects on other areas of business performance. Therefore, promoting a positive safety culture appears to be the best way to ensure healthy, safe as well as productive work environments.

5. SAFETY CULTURE

The concept of Safety Culture came into international usage following a report by the International Atomic Energy Agency (IAEA) in 1991, after the Chernobyl accident (Flin *et al.*, 2000) which led to safety culture being defined as an organizational atmosphere where safety and health is understood to be, and is accepted as, the number one priority. Since then, a number of organizations and researchers have developed the concept, applying it more widely to non-nuclear industries and linking it to the need for preventative approaches to OSH and to human and behavioural aspects of effective OSH management (ILO, 2005).

5.1. DEFINING SAFETY CULTURE

A safety culture generally refers to the extent to which very individual and every group of the organization 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 academic literature, and examples of selected definitions are shown in Table 1.

Table 1: Definitions of safety culture

Reference	Definition
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 organization. It is a sub-element of the overall organizational 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'

Reference	Definition
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)	Those aspects of the organizational culture which will impact on attitudes and behaviour related to increasing or decreasing risk
Cooper (2000)	Culture is 'the product of multiple goal-directed interactions between people (psychological), jobs (behavioural) and the organization (situational); while safety culture is 'that observable degree of effort by which all organizational members directs their attention and actions toward improving safety on a daily basis'
Mohamed (2003)	A sub facet of organizational culture, which affects workers' attitudes and behaviour in relation to an organization'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 organization owns in safety

As a summary of above definitions, safety culture is a subset of the corporate organizational culture that includes a set of enduring values and attitudes regarding safety issues, shared by every member of every level of an organization. In a more descriptive elaboration safety culture can be regarded as "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 organization's health and safety management" (HSC, 1993, p. 23).

The concept of safety culture is often presented separately from an organization's other characteristics, such as the work schedule, technology, business strategy and financial decision-making (Reiman and Oedewald, 2004). Reiman and Oedewald (2004) revealed that this conceptual separation of safety culture reduces the term to refer only to factors that are clearly connected with safety, such as safety attitudes and safety values.

5.2. COMPONENTS OF SAFETY CULTURE

Creating a robust safety culture is about more than removing hazards and institutionalizing safety procedures. It's about working with people to change their attitudes, behaviours and thoughts, and improve their situational awareness - all within the dynamics of today's world. Ardern (2009) illustrated three areas to be considered when developing a safety culture, attitude, environment and systems (Figure 1). According to Ardern (2009), attitudes, both personal and organizational, affect development of a safety culture in a workplace. The environment in which people work and the systems and processes in an organization also influence the safety culture. Therefore, each organization needs to consider all of these aspects in developing and nurturing a safety culture that suits the organization and the individuals within it.

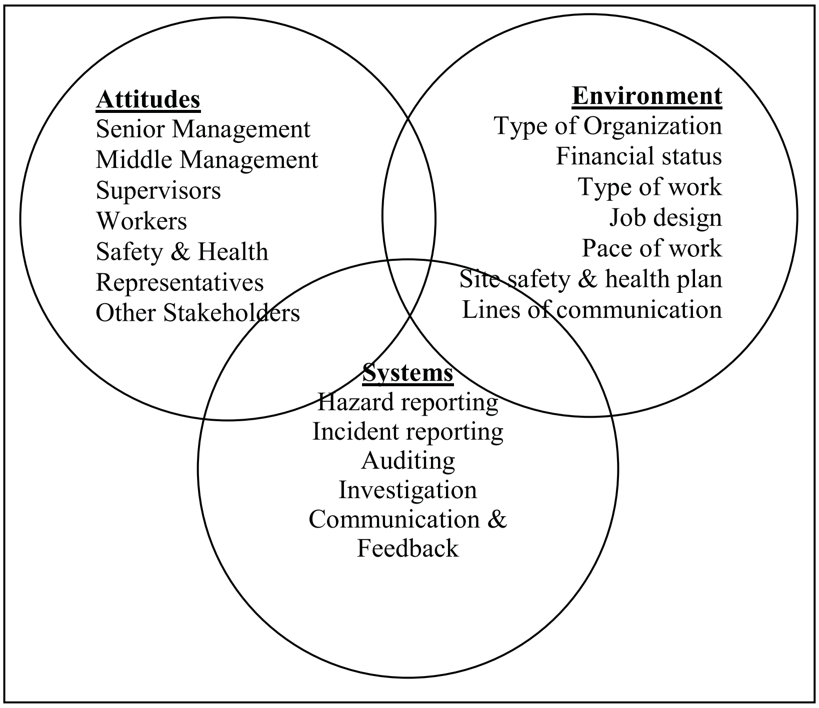

Figure 1: Components of Safety Culture
(Source: Ardern, 2009)

6. STRENGTHENING THE SAFETY CULTURE

Strong a safety culture can be an effective tool for improving safety within any organization (Vecchio-Sudus and Griffiths, 2004). Hale (2000) has listed a number of elements for a strong safety culture. These include importance to safety; involvement of workers at all levels; role of safety staff; the caring trust (that all parties to have a watchful eye and helping hand to cope with inevitable slips and blunders); openness in communication; belief in safety improvements; and integration of safety in to the organization. Vecchio-Sudus and Griffiths (2004) also reviewed strategies to strengthen and further promote a safety culture. They identified six strategies altogether as follows;

(1) *Changing attitudes and behaviours*: Safe behaviours can be enhanced by capitalizing on activities such as verbal instructions, training, and warning signs. Nevertheless, if things are communicated in the way that the work is easier, and the task can be finished earlier and thus rewarded with monetary incentive, then certainly employees will be cutting corners, may not be observing safety rules, not wearing personal protective equipment, and ultimately not working safely. Long-term values include employees being able to work without injury so they can continue to provide earning for both the company and for her/his family.

(2) *Management commitment*: Management plays a key role in promoting a positive safety culture. This can be best demonstrated by allocating resources, time, walk the talk, inspections, by participating in risk assessments and consultative committee meetings, and by completing actions.

(3) *Employee involvement*: For a positive safety culture, employees' involvement, ownership and commitment is necessary; in particular empowerment promotes feelings of self-worth, belonging and value. Employees should be involved in training, consultation about noise, machinery isolation, sound barriers, job rotation, PPE, and wearing different earmuffs.

(4) *Promotional strategies*: In order to enhance safety awareness amongst employees, promotional strategies to be used should include the following:

    (i) Mission statements, slogans and logos;

    (ii) Publish materials (library, statistics, newsletters);

    (iii) Media (posters, displays, audiovisual, e-mail, Internet).

(5) *Training and Seminars*: Training activities should include short talks, group meetings, training for personal fitness, hygiene, workplace stress and responsibilities towards safety (including compliance with rules and regulations, hazard identification and risk assessment, incident investigation and job safety analysis). De Silva and Wimalaratne (2012) recognized three aspects in this regard such as, Implementation of OSH policies and programmes, Site specific OSH programmes, and OSH education: orientation and specialized training.

(6) *Special campaigns*: This item should include Health and Safety Week, health promotion, safety inductions, emergency response, incident reporting and investigation, risk assessment, introduction to existing health, safety and environment management systems.

Further, De Silva and Wimalaratne (2012) identified eight strategies, namely (1) *OSH meetings*, (2) *Soliciting the involvement of the workers for OSH decision making*, (3) *OSH incentive programmes*, (4) *Safety operations and proper time management* (5) *Identification and monitoring of work pressure*, (6) *OSH inspections*, (7) *Proactive performance measurement*, and (8) *Introducing a set of OSH rules to the site*, to enhance the safety culture in an organization.

Moreover, Choudhry *et al.* (2007) asserted that a positive safety culture comprises of five components which include: *management commitment to safety; management concerns for the workforce; mutual trust and credibility between management and employees; workforce empowerment;* and lastly *continuous monitoring*, corrective action, review of system and continual improvements to reflect the safety at the organization. In another research conducted by Pidgeon and O'Leary (2000), the authors argued that a good safety culture may be promoted by four factors: (1) *Senior management commitment to safety*; (2) *Realistic and flexible customs and practices for handling both well-defined and ill-defined hazards*; (3) *Continuous organisational learning through practices such as feedback systems, monitoring and analysing*; and a (4) *Care and concern for hazards which is shared across the workforce.*

When comparing these factors identified by different authors, it can be observed that they, with slight overlaps among them, do point at the same direction. Management commitment to OSH, employee involvement and empowerment, proper OSH systems and feedback mechanisms, continuous monitoring of OSH systems can be identified as the most important factors that help to strengthen the safety culture with in a organization and ultimately help it to be sustainable n the long run.

7. CONCLUSIONS

This paper reviewed the existing literature on organizational sustainability, OSH and safety culture and provided essential clarification by providing appropriate empirical evidence and theoretical development. The responsibility for providing and building the necessary OSH culture, which goes beyond just preventing injuries in the construction sites, is a shared duty among the stakeholders.

Over the years, management of occupational safety and health (OSH) in organizations has become a very complex multi-functional science that focus not only on safety and health of the employees but also on supporting quality initiatives aimed at continuous improvement of the organization, hence the organizational sustainability. Though safety and health at work have traditionally been approached mainly by means of legislation and enforcement measures, researchers have identified 'safety culture' as the best way to promote OSH within an organization (Pidgeon and O'Leary 2000; Vecchio-Sudus and Griffiths, 2004). The concept of safety culture has been researched by many authors (Hale, 2000; Mohamed, 2003; Fang *et al*., 2006). They agree that safety culture refers to a set of enduring values and attitudes regarding safety issues, shared by every member of every level of an organization.This study revealed that safety culture consists of three main components, namely, attitudes- both individual and organizational, environment of the organization and OSH systems occupied by the organization. The study further demonstrated that strengthening the safety culture can be an effective tool for improving sustainability of the organization. Factors that influence strong safety culture identified under the final section of the paper were Management commitment to OSH, employee involvement and empowerment, proper OSH systems and feedback mechanisms, and continuous monitoring of OSH systems.

As a concluding remark, according to the literature findings, within a strong safety culture, employees not only feel responsible for their own safety, but are responsible for their peers' safety, and the organizational culture supports them acting on their responsibility. Within a strong safety culture, the organization's formal management systems and leaders' informal management practices facilitate caring by encouraging, recognizing, and reinforcing safe behaviours. These characteristics may lead the organization to achieve best quality working environments and thereby help the organization to be sustainable as a firm. So it is established that OSH and organizational sustainability are two concepts that are not by far discrete as they first appear to be and it can be asserted that OSH is an important aspect for any organization that seeks to be sustainable.

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TECHNO-ECONOMIC FEASIBILITY OF INTEGRATION OF GREEN TECHNOLOGIES FOR AFFORDABLE HOUSING

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ABSTRACT

The conventional construction technology along with spiralling cost of traditional building materials makes the housing unaffordable or a distant dream for an average income salaried person. The aim of a paper is to design an affordable green building model for an Economically Weaker Section (EWS) housing scheme to compare energy, carbon footprint and water performance. In this, a single dwelling unit plan is worked out for a EWS housing scheme using the identified green materials & techniques and compared with conventional material & techniques of construction. The study reveals that the integrated sustainable technologies like application of energy efficient building construction materials, implementation of water management and energy management techniques make the housing schemes energy efficient and cost effective to the economically weaker section of urban area.

Keywords: *Affordable Housing; Economically Weaker Section; Energy Efficient Building; Sustainable Technologies.*

1. INTRODUCTION

The housing shortage affects mostly the economically weaker sections (EWS) and low income groups (LIG), and the younger group of urban-urban migrants changing cities in search of better prospects. In India at the end of the 10th five year plan the overall shortage has been estimated at close to 25 million dwelling units. Affordable houses may be taken as houses ranging from about 300 square feet for EWS, 500 square feet for LIG and 600 square feet to 1200 square feet for middle income groups (MIG), at costs that permit repayment of home loans in monthly instalments not exceeding 30% to 40% of the monthly income of the buyer (SP 7:2005). In terms of carpet area, a EWS category house would be taken as having a minimum 25 square metres and of an LIG category house would be limited to a maximum of 48 square metres. The carpet area of an MIG house would be limited to a maximum of 80 square metres (Menon, 2009). Depending on household income, different housing schemes i.e. high income groups (HIG), MIG, LIG and EWS are categorized. The cost of housing scheme mainly depends on the carpet area and rate of conventional construction. The components of building block of traditional materials such as brick, stone, natural river sand, ordinary portland cement, wood, paints, steel etc. have environmental implications during the life cycle at various stages like manufacturing, transportation, construction to demolition (Raut *et al.*, 2011). The spiralling cost of such traditional building materials makes the housing unaffordable or a distant dream for an average income salaried person. This leads to have more and more research to find out alternative low cost, energy saving, eco-friendly, recyclable solid wastes from industries, agricultures, mines for effective utilization as a partial or full replacement of such components for uses in buildings and infrastructures (Pattanaik,

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2010). Although research had been well established commercially very few materials have been used in practice.

In view of developing techno-economical viable solution for affordable housing the present paper elaborates the detailed methodology for integration of locally available green materials, alternate water management and energy management techniques which are climatically appropriate. The methodology is well supported with a typical designed plan of a EWS dwelling unit over the study location.

2. METHODOLOGY

In order to design an affordable green building model for an economically weaker section (EWS) the sizing for dwelling unit is worked out (SP 7:2005). Identification and selection of green construction materials and techniques was reviewed and suitably considered for the proposed EWS housing scheme. The block budgeting for the dwelling unit along with carbon footprint reduction was estimated.

3. TYPICAL CONSTRUCTION OF A EWS HOUSING SCHEME

Figure 1 indicates typical plan of a single storied EWS dwelling unit. Considering the maximum plot area of 60 m^2 with the maximum super built-up of 30 m^2, ventilated area was considered to be 15% on the front and rear walls of the dwelling unit (SP 41:1987). A EWS housing scheme is considered with both side walls as common walls with front and rear plot margin. Dwelling cost and energy consumption calculated by using the identified green materials and techniques and compared with conventional material and techniques of construction. The appropriate green construction materials, water and energy management techniques are elaborated further.

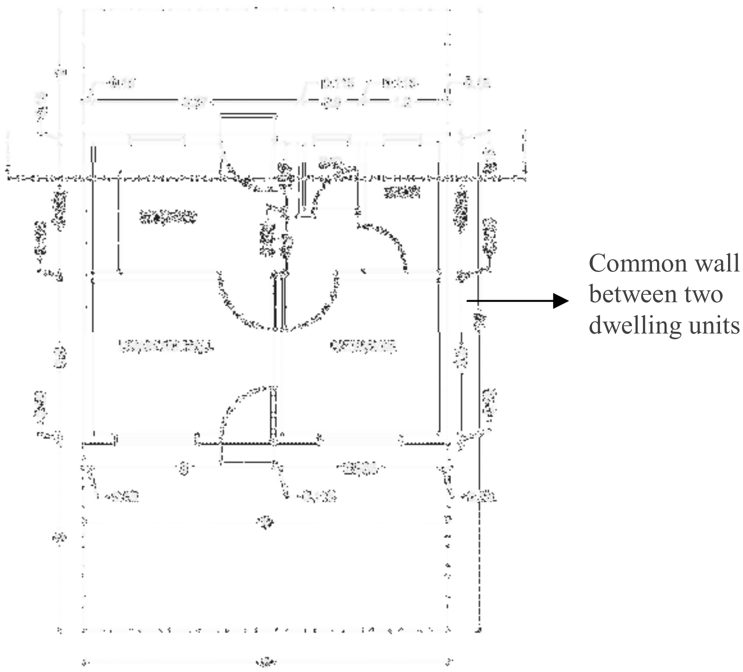

Figure 1: Typical Plan of Single EWS Dwelling Unit

4. GREEN CONSTRUCTION MATERIALS AND TECHNIQUES

Identification and selection of green construction materials was reviewed and suitably considered for the proposed EWS housing scheme. Every year India generates around 90-100 MT of bagasse as by-product of the sugarcane industry, India is the second largest sugarcane producer in the world after

Brazil (Sengupta, 2002). Typically, as a substitute for conventional masonry, cement and sand use of sugarcane bagasse ash (SBA) is recommended as a low cost sustainable solution (Madurwar *et al.*, 2013). As a substitute for nominal size crushed aggregate use of naturally available rounded aggregates/gravels and maximum size of crushed aggregates are recommended (Mehta and Monteiro, 1993). Further, use of bamboo (BMTPC) is recommended as door & windows, flooring, roofing sheets and shuttering and scaffolding. The particle fibre board (Satta and Steve, 2008; Cristel *et al.*, 2010) made from bagasse is recommended as a sustainable false ceiling solution. Roof top rainwater harvesting (Gupta and Ralegaonkar, 2006) and application of active solar energy gadgets are recommended as the sustainable water and energy management solution.

4.1. SUGARCANE BAGASSE ASH (SBA)

Sugarcane is a major crop in many tropical countries. The production process generates bagasse as a waste, which is used as fuel to stoke boilers that produce steam for electricity cogeneration. The final product of this burning is residual sugarcane bagasse ash. Ash stands out among agro-industrial wastes because it results from energy generating processes. Tables 1, 2 and 3 show the physical characterization, particle size distribution and chemical composition of sugarcane bagasse ash.

Table 1: Physical Characterization of SBA

Properties	Specific Gravity	Mean Particle Size, D60 (μm)
SBA	2.4	45.0

Table 2: Particle Size Distribution of SBA

% Distribution	Gravel	Sand	Silt	Clay
SBA	0.61	75.15	23.04	1.20

Table 3: XRF of SBA

Elements (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	LOI
SBA	59.50	2.40	3.34	14.75	2.11	0.92	8.90

The percentage silica present indicates the suitability of SBA as pozzolanic material (IS 456:2000) for partial cement and sand replacement and also for making building bricks by mixing with cement and sand in different proportions (Suvimol and Daundrudee, 2008). The SBA-sand-cement combination had resulted in production of lighter brick material as per the recommended Indian standard. It was observed that bricks with the 10% addition of cement to SBA and sand exhibits a compressive strength of 5 MPa which is almost 1.7 more times more than the conventional clay bricks (3 MPa) and satisfies the requirements in IS 2185 (Part – I):1998 and BIS, SP 21:1983 for a building material to be used in the indoor structural applications. Apart from that, SBA building brick manufacturing process results in 60% reduction in energy consumption over the conventional building bricks.

Mortars and concretes with SBA as sand replacement were investigated by several researchers. The results indicated that the SBA samples presented physical properties similar to those of natural sand. The mortars produced with SBA in place of sand showed better mechanical results than the reference samples (Sales and Lima, 2010). The physical properties of concrete containing ground bagasse ash (BA) including compressive strength, water permeability and heat evolution were reviewed. Grounded bagasse ash from the sugar factory was used as a replacement for Portland cement at 10, 20, and 30wt% of binder. The water to binder (W/B) ratio and binder content of the concrete were held constant at 0.50 and 350 kg/m3 respectively. The results showed that, at the age of 28 days, the concrete samples containing 10–30% ground bagasse ash by weight of binder had greater compressive strengths than the controlled concrete (concrete without ground bagasse ash), while the water permeability was lower than the controlled concrete. Concrete containing 20% ground bagasse ash had

1.13 times higher compressive strength than the controlled concrete. The water permeability of concrete was observed to be reduced as the fractional replacement of ground bagasse ash was increased. For the heat evolution, the maximum temperature rise of concrete containing ground bagasse ash was lower than the controlled concrete. It was also found that the maximum temperature rise of the concrete was reduced 13, 23, and 33% as compared with the controlled concrete when the cement was replaced by ground bagasse ash at 10, 20, and 30wt% of binder, respectively (Nuntachai *et al.*, 2009). Tables 4 and 5 show the cement replacement potential of SBA in ordinary and high strength concrete.

Table 4: Cement Replacement, Water to Binder Ratio (w/b) and Compressive Strength of Various Agro-Wastes for Ordinary Concrete

Agro-waste	Cement Replacement (%)	w/b ratio (%)	Compressive Strength, 28 Days (MPa)	Source
Bagasse Ash	30	0.53	32.00	(Amin, 2011)

Table 5: Cement Replacement, Water to Cement Ratio (W/C) and Compressive Strength of Various Agro-Wastes for High Strength Concrete.

Agro-waste	Cement Replacement (%)	w/c ratio (%)	Compressive strength, 28 Days (MPa)	Design Strength, (MPa)	Source
Bagasse Ash	10	0.30	65	65	(Rukzon and Chindaprasirt, 2012)
	20	0.30	67		
	30	0.30	68		

4.2. NATURAL AGGREGATES / GRAVELS

The importance of using the right type and quality of aggregates cannot be overemphasized. The fine and coarse aggregates generally occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy. Fine aggregates generally consist of natural sand or crushed stone with most particles smaller than 5 mm (0.2 in.). Coarse aggregates consist of one or a combination of gravels or crushed stone with particles predominantly larger than 5 mm (0.2 in.) and generally between 9.5 mm and 37.5 mm (3⁄8 in. and 11⁄2 in.). Some natural aggregate deposits, called pit-run gravel, consist of gravel and sand that can be readily used in concrete after minimal processing. Natural gravel and sand are usually dug or dredged from a pit, river, lake, or seabed. Crushed stone is produced by crushing quarry rock, boulders, cobbles, or large-size gravel. Crushed air-cooled blast-furnace slag is also used as fine or coarse aggregate. The aggregates are usually washed and graded at the pit or plant. Some variation in the type, quality, cleanliness, grading, moisture content, and other properties is expected. Close to half of the coarse aggregates used in Portland cement concrete in North America are gravels; most of the remainder are crushed stones (ASTM C 637, C 638 and Guidelines for Affordable Housing in Partnership, Ministry of Housing and Urban Poverty Alleviation, GOI, 2009).

Maximum size of aggregate affects the workability and strength of concrete. It also influences the water demand for getting a certain workability and fine aggregate content required for achieving a cohesive mix. For a given weight, higher the maximum size of aggregate, lower is the surface area of coarse aggregates and vice versa. As maximum size of coarse aggregate from a mix reduces surface area of coarse aggregate required in a mix increases. Higher the surface area, greater is the water demand to coat the particles and generate workability. Smaller maximum size of coarse aggregate will require greater fine aggregate content to coat particles and maintain cohesiveness of concrete mix. Hence 40 mm down coarse aggregate will require much less water than 20 mm down aggregate. In other words for the same workability, 40mm down aggregate will have lower water/cement ratio, thus higher strength when compared to 20mm down aggregate. Because of its lower water demand, advantage of higher maximum size of coarse aggregate can be taken to lower the cement consumption. Maximum size of aggregate is often restricted by clear cover and minimum distance between the reinforcement bars. Maximum size of coarse aggregate should be 5 mm less than clear cover or minimum distance between the reinforcement bars, so that the aggregates can pass through the reinforcement in congested areas, to produce dense and homogenous concrete. It is advantageous to use greater maximum size of coarse aggregate for concrete grades up to M 35 where mortar failure is predominant. Lower water/cement ratio will mean higher strength of mortar and will result in higher strength of concrete. However, for concrete grades above M40, bond failure becomes predominant. Higher maximum size of aggregate, which will have lower area of contact with cement mortar paste, will fail earlier because of bond failure. Hence for higher grades of concrete (M40 and higher) it is advantageous to use lower maximum size of aggregate to prevent bond failure (ASTM C 637, C 638 and Guidelines for Affordable Housing in Partnership, Ministry of Housing & Urban Poverty Alleviation, GOI, 2009).

4.3. Bamboo Based Products

Bamboo has a long and well established tradition for being used as a construction material throughout the tropical and sub-tropical regions of the world (Rahman *et al.*, 2011). With the rising global concern, bamboo is a critical resource as it is very efficient in sequestering carbon and helps in reduction of Green House gas emissions. In the modern context when forest cover is fast depleting and availability of wood is increasingly becoming scarce, the research and development undertaken in past few decades have established and amply demonstrated that bamboo could be a viable substitute of wood and several other traditional materials for housing and building construction sector and several infrastructure works. Its use through industrial processing have shown a high potential for production of composite materials and components which are cost-effective and can be successfully utilised for structural and non-structural applications in construction of housing and buildings (Asamoah and Owusu, 2011; Mahzuz *et al.*, 2011). Main characteristic features, which make bamboo as a potential building material, are its high tensile strength and very good weight to strength ratio. The strength-weight ratio of bamboo also supports its use as a highly resilient material against forces created by high velocity winds and earthquakes. Above all bamboo is renewable raw material resource from agro-forestry and if properly treated and industrially processed, components made by bamboo can have a reasonable life of 30 to 40 years. Various uses and applications in building construction have established bamboo as an environment-friendly, energy-efficient and cost-effective construction material. Bamboo can be used for shutters of door and windows, flooring, roofing sheets and shuttering & scaffolding. Bamboo flooring, bamboo roofing and bamboo board are developed interior designing material developed by using modern scientific methods from superior quality bamboo. Bamboo flooring is an attractive alternative to wood or laminate flooring (BMTPC).

4.4. Fibreboards / Particleboard / Thermal Insulator

Bagasse can be made into soft boards, medium density fibreboards or particleboards, as well as high density hardboards. It can be upgraded by bonding with phenolic resin, producing boards and panels that are strong, durable, heat and moisture resistant, light weight, and easily transportable. Bagasse-based thermal insulation shows thermal conductivity in the range 0.047 – 0.050 W/mK (Pappu *et al.*, 2007).

Table 6: Physico-Mechanical Properties of Particle Insulation Board Made from SBA

Agro-Waste	Density (Kg/m3)	Thermal Conductivity (W/mK)	Source
Bagasse	90-140	0.047-0.050	(Krishpersad, 2006)

Pitched roof is proposed for the construction as it reduces heat gain due to radiation, in turn reduces cooling load. Considering the need for developing alternate eco- friendly, energy efficient and cost effective roofing sheets, building materials and technology promotion council (BMTPC) and Indian plywood industries research and training institute (IPIRTI) had jointly developed a technology for manufacturing bamboo mat corrugated sheets (BMCSs). These sheets were found to be resistant to water, fire, decay, termites, insects, etc. They were light but strong and possess high resilience and offer better thermal comforts (BMTPC). The pitched roof technology along with bamboo truss is suitable for the selected climatic condition. False ceiling of bagasse-cement panels is provided to the pitched roof of EWS dwelling.

4.5. Water and Energy Management Techniques

Community based roof top rainwater harvesting system shall be recommended for the collection and storage of rain water for flushing and gardening purpose. The design criterion mainly depends on the roof area and maximum average precipitation of that area for one day. According to EA and UKWIR, 1996 rainwater harvesting appears to be relatively more pragmatic and cost-effective option compared to grey water recycling. BSRIA, 1998 has investigated the impact of low water consuming devices and made a scenario-based assessment of potential savings in water and cost in various types of buildings. The study showed the saving potential of up to 24% as compared current consumption. This reduction saves not only on water supply costs but also on water treatment costs. Solar based water heating system along with solar lighting and cooling system shall be implemented to save the energy.

5. Results and Discussion

In order to provide the techno-economic feasible solution for EWS housing scheme several green materials and techniques were scientifically examined and recommended over the study location. The optimal planning for the multiple EWS dwelling units have been demonstrated with the concept of common wall system that itself saves 50% masonry cost. Generally carbon emission is often a by-product of energy consumption; each clay brick fired with fossil fuel conservatively releases 0.4250 kg of carbon dioxide greenhouse gas into the atmosphere. The recommended SBA brick releases 0.1667 kg of carbon dioxide greenhouse gas which intern results in 2/3rd of emission reduction as compared to conventional burnt clay bricks. Along with SBA bricks the wall thickness of external wall can be modified from 9” to 6” as the compressive strength is much significant compared to clay bricks. Utilization of 6” smart SBA bricks saves around 33% of production material as well as the embodied energy and makes the masonry more economical. The recommended SBA had a potential to replace 30% of cement from all grades of mortars and concretes required for EWS housing. Proper mix & structural design also saves the cement consumption from concrete. The 20 mm down crushed aggregate from the concrete is replaced by 40 mm down locally available natural/rounded aggregates ensures minimum 20% of cement savings. The recommended alternate roofing of bamboo over the conventional RCC slab saves the entire carbon emission of reinforcement steel, cement and aggregates. The extensive use of bamboo products like bamboo roof, bamboo flooring and bamboo shutters for door and window makes the building more economical and energy efficient. The thermal insulation behaviour of SBA ceiling panel makes the built environment pleasant and saves the additional energy required for cooling. Community based Rain water harvesting System for flushing and gardening makes the dwelling unit self sustainable and saves equal amount potable water. Implementation of centralized PV solar energy system for room lighting (Solar LED lamp) and cooling (Ceiling Mounted Solar Fan) purpose saves the conventional electrical energy and makes the dwelling unit energy efficient.

6. Conclusions

Collective housing schemes incorporating raw or treated local building materials along with appropriate water and energy management techniques have the potential to provide climatically and socially viable, energy efficient, sustainable and affordable housing to the economically weaker section of the society.

Following conclusion are drawn for the suggested EWS housing scheme.

- SBA masonry products are light weight, thermally insulated, energy efficient and save 40-60% cost of masonry construction.
- Use of SBA as cement and sand replacement saves around 30% cost and carbon emission from masonry and concrete.
- Use of maximum size of locally available natural/rounded/crushed aggregates saves up to 20% of cement from concrete making the EWS housing more economical and energy efficient.
- Use of treated bamboo products in EWS housing schemes makes the building affordable.
- Suitably designed community roof top rainwater harvesting system and ultra low flow fixtures saves up to 50% of potable water.
- Climatically suitable alternate solar energy gadgets save electrical energy and makes EWS housing energy efficient.

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THE NEED FOR AN INTEGRATED COST MODELLING FRAMEWORK FOR BUILDING INFORMATION MODELLING

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ABSTRACT

Building Information Modelling (BIM), a revolutionary concept in the construction industry, produces an object-oriented, intelligent and parametric digital representation of the construction facility, which requires a collaborative participation of members of the design team members. These emphasize that BIM has characteristics of sustainable procurement strategies. Open BIM standards developed by buildingSMART International, are the most popular data standards for BIM to share digital construction information within the design team and beyond throughout the life cycle of the project. Other proprietary BIM standards are also extensively used, but they often have limitations on sharing information across all stakeholders. Even though BIM conceptually is an integrated approach for all project team members, not all functions are performed within the common platform. Project participants use their domain specific tools often with proprietary standards, and share the results translated to common standards. BIM enables a live information model with which all project participants can actively interact. This enables minimizing of errors and early clash detection, paving the way to sustainable project delivery methods. However, Quantity Surveying functions within a BIM based project delivery was found to be least interactive. This has hindered the real benefits receivable from a BIM implementation. Since, a cost model will provide critical information required for decision making at various stages, an up-to-date cost model is critical for a BIM based project delivery. While a variety of software tools is used for this purpose, a standardized method is not found to share cost information effectively with BIM. This study aims to develop a suitable framework for cost modelling for a BIM implementation in order to help develop BIM standards for cost modelling. This paper contains the preliminary findings of an ongoing research.

Keywords: *Building Information Modelling; Cost Modelling; Open BIM Standard; Quantity Surveying.*

1. INTRODUCTION

Procurement of a construction facility deals with design, construction and operation stages where sustainability is a major requirement. Building Information Modelling (BIM), an upcoming modern day concept, is capable of sharing information between the project team members and across the software applications which are commonly used in the procurement process of the construction facility (buildingSMART, 2013a), emphasizing the characteristics of a sustainable procurement strategy.

Although conceptually BIM is a fully integrated approach where all the functions are performed in a common platform, there are major limitations in practical implementation. Mitchell (2012) quite clearly points out that for BIM to be truly successful in providing better buildings all of the dimensions are to be embraced. Hence this research aims to develop a suitable framework for one of the major activities in procuring a construction facility; cost modelling. It should be noted that this paper is based on the preliminary findings of an ongoing research.

2. BUILDING INFORMATION MODELLING (BIM)

The BIM is a "revolutionary concept of using computer simulation in the construction industry" (RICS, 2012) which has already attracted the attention in Architecture, Engineering and Construction/

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Facility Management (AEC/FM) field (Zhiliang *et al.*, 2010a). Moreover, Zhiliang *et al.* (2010b) pointed out that BIM is designed in a way that it is capable of facilitating information sharing in a construction project, among the stakeholders in different phases in order to make better decisions.

To date, in most of the design firms, the main focus on (BIM) implementation has been simply about the way the parametric 3D modelling software works (Mitchell, 2012). However in 2007, U.S. General Services Administration (GSA) emphasised that 3D models alone are not BIM models as geometric representation is only a part of the BIM concept, and its true concept and true intention is represented by the "I" in BIM; information.

As defined by Associated General Contractors of Georgia (AGC) in 2013,

> BIM is the development and use of a computer software model to simulate the construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and improve the process of delivering the facility. (para.2)

Moreover, Hamil (2012) highlights that the problem of silo working and badly coordinated documentation in the construction industry will be greatly reduced through the adoption of BIM, and for this to be achieved, interoperability is critical. But, Bernstein and Pittman (2004) clearly points out that poor software interoperability has long been regarded as an obstacle to industry efficiency in general and to BIM adoption in particular. Among different levels of interoperability, interoperability through open standards is considered to be the most applicable (Hamil, 2012).

2.1. OPEN BIM

Amid the various data standards for BIM, Industry Foundation Classes (IFC) is a non-proprietary open standard published by International Alliance for Interoperability (IAI), to define AEC objects consisting properties and/or geometry (Mitchell, 2013). The importance of IFC standards in the BIM process is highlighted as it is a standard for sharing of digital construction information throughout the whole life cycle of a building project, globally, across the disciplines in the AEC/FM industry (buildingSMART, 2013b).

This open standard is adopted by Open BIM; an initiative of the neutral, non-profit buildingSMART alliance and several developers of BIM based software (Johnson, 2012). Furthermore, Johnson (2012) explains that Open BIM aims to accelerate the adoption of BIM in the AEC industry by providing common definitions, requirements, and branding for building projects, helping to overcome the challenges that can impede the collaboration among architects, engineers, contractors, and project owners that is so vital to an effective BIM workflow.

No matter what the scale of the project is, according to buildingSMART (2013c), the current AEC/FM industry is facing the following key collaboration issues.

- Lack of real coordination workflow
- Lost information during data conversion
- Interpretation issues of data from other party
- Limited utilization of building data created by others
- Missing follow-up of design changes between the trades
- Lack of overall coordination environment for multiple trades
- Lack of detailed model for construction

The open standards are believed to be capable of providing solutions for the above collaboration issues. It is because open workflows provide different trades with the option to use the best tools for their own purpose without losing the benefits of model-based collaboration, provides integrity and ownership of BIM project data and transparency of workflow is available.

The official definition of Open BIM is defined by buildingSMART (2013c) as follows.

> Open BIM is a universal approach to the collaborative design, realization and operation of buildings based on open standards and workflows. Open BIM is an initiative of buildingSMART and several leading software vendors using the open buildingSMART Data Model.

3. COST MODELLING

Among the critical activities for any construction project, cost modelling is a vital task to be performed throughout the lifecycle of a building project (Zhiliang *et al.*, 2010b), especially from inception to completion of project. As defined by Ferry *et al.* (1996, p.110),

> Cost modelling is the symbolic representation of a system, expressing the content of that system in terms of the factors which influence its cost. In other words, the model attempts to represent the significant cost items of a cash flow, building or component in a form which will allow analysis and prediction of cost to be undertaken. Such a model must allow for the evaluation of changes in such factors as the design variables, construction methods, timing of events, etc.

Though quantities of the building project can be extracted from BIM model, the estimating process is currently not an automatic process in BIM environment as "work must be performed which identifies and maps the objects in the CAD model to a format which traditional estimators are comfortable with" (Hannon, 2007). According to Bailey (2010), even in USA, though progress has being made with the use of the “OmniClass” coding system, at this stage “published documentation only provides a level of codes suitable for conceptual and early schematic models and estimates”. It should be noted that thus far 5D modelling is performed through the combination of BIM authoring software combined with 3rd party software for measurement and estimating (Boon *et al.,* 2011).

4. CURRENT PRACTICE OF COST MODELLING IN BIM ENVIRONMENT

4.1. INDUSTRY FOUNDATION CLASSES (IFC) USE CASES

According to background research, IFC standard has been applied in various use cases with regard to construction cost estimation by various researches (Zhiliang *et al.,* 2010a). Here cost estimation consists traditionally of the application of appropriate unit rates to the measured finished quantities of the proposed structure (Ashworth, 1994). Faraj *et al.,* (2000) had developed a web and IFC based construction computer integrated environment named WISPER (Web-based IFC Shared Project Environment), in which the IFC based object-oriented database can assist estimators. Through this application, estimators can retrieve quantities of elements, grouped together based on their type, in Ms Excel spreadsheet. Then the estimators have to cost the element groups in the spreadsheet to obtain a cost summary of the project. IFC - compliant lifecycle cost prototype tool developed by Fu *et al.,* (2004), is capable of calculating and demonstrating a breakdown of the overall life cycle cost of the building, after assigning all the building elements for the certain construction type. Tanyera and Aouada (2005) had proposed a web-based 4D planning prototype tool comprising of a basic cost estimator, which can automatically calculate main building elements and their quantities by using the submitted IFC file. In order to calculate the total material cost, the estimator has to fill the unit costs of the building elements.

4.2. COST ESTIMATION SOFTWARE

Apart from the above use cases, several BIM based costing software has been developed by various vendors. The following table shows a summary of the widely used costing software.

Table 1: Costing Software Details

Costing Software	How it Works	Source
MS Excel	This is the simplest method to quantity takeoff within Revit. Here, accurate quantities are extracted from the Revit BIM, output as a text file. Then these data are imported to an Excel spreadsheet file, which used by the Quantity Surveyors for pricing of items.	BIM Wiki (2013)
Success Estimator	Using Success Estimator internally cost baselines for Revit projects can be quickly developed and can deliver optimal designs that is within the clients' budget. Here, the API links between Revit and Success Estimator have to establish successfully. This also has the capability to produce quick cost estimates on small, fast-track projects. Through the accurate costs extracted from the Success Estimator, the QS can develop more realistic cost estimates.	US COST (2013)
Innovaya	Innovaya Design Estimating is a cost estimating software tool to automatically generate an estimate for the entire project. The program integrates Autodesk Revit seamlessly with RS Means Assembly Database, and it uses Sage Timberline Estimating, to calculate project costs instantly and accurately based on City Cost Index in North America, while providing powerful, flexible, and fully customizable estimating reporting capabilities. Quantities can be extracted based on building element types and dimensions. This also can detect the design changes from the Revit model and automatically update the quantities.	Innovaya (2013)
CostX	This is useful for integrating data-centric applications such as specification management and cost estimating with BIM. These approaches typically use the Open Database Connectivity (ODBC) database to access the attribute information in the building model, and then use exported 2D or 3D CAD file to access the dimensional data. For accurate estimation of cost and variations as they occur, CostX features bi-directional ties for design solutions, including ODBC based integration between CostX and Revit. These ties automatically detect the changes and graphically display the results, which allow to easily seeing the areas that have changed and quickly cost the model.	Exactal (2013)
Vico Office Suite	Vico Cost Planner is a powerful model-based cost estimating solution. Based on the concept of Target Cost Planning, Vico Cost Planner provides an environment for an evolving cost estimate that readily compares one version to another and any version to the original Target Cost Plan. Vico Cost Explorer is the first model-based budgeting application that allows the extended project team to visually understand which aspects of the project are contributing to changes in cost. Pouring over rows and rows of spreadsheet data is a thing of the past.	Vico Software (2013)
Tocoman iLink	Tocoman iLink is a plug-in to a building modelling application. It is used to calculate quantities either from designers or contractor's building models. These quantities can be used as such or with the Tocoman Express product, in estimating and scheduling applications.	Tocoman Group (2010)

4.3. *MAJOR CHARACTERISTICS OF CURRENT PRACTICE OF COST MODELLING IN BIM ENVIRONMENT*

After reviewing the IFC use cases and BIM based costing software, the major characteristics of the current practice, it is quite clear that all those except MS Excel comprise of the following characteristics (Zhiliang *et al.*, 2010a).

- Operating in 3D-based platform obtained either from independent developing or professional BIM based design software.
- Capable of extracting input data from IFC file.
- Since there is no enforced specification, the software follows the coding system developed by the industry association.
- Applicable for estimating from conceptual design to detail design.
- The quantity extraction is not subjected to uniform calculation rules but is based on object types and their dimension.
- Cost estimation is based on the cost items generated by the professional and experienced cost estimators.

Through the literature, it was identified that the current practice has several problems and it does not clear the path to confiscate the obstacle of the interoperability inefficiencies to adopt BIM (Mendez, 2006).

5. KEY REQUIREMENTS OF COST MODELLING IN BIM ENVIRONMENT

Through the literature search, the main requirements of cost modelling in the BIM environment were identified. Since Zhe (2009) suggested a comprehensive list of requirements, those were adapted in this research.

Table 2: Key Requirements of Cost Modelling in BIM Environment

No	Key Requirements	Description
1	Automatically import design result	The estimators can make use of the design result of IFC data automatically. There is no need to manually identify the drawing and to establish the model which could eliminate manual reworks, increase speed and improve productivity.
2	Interactive 3D visualization	Users can enjoy the best performance of 3D building model navigation and object details examination. The 3D building elements and cost items are highly interactive and selectable. Support interactive data modifications.
3	Intelligent match	Building elements can be automatically linked to cost items through the intelligent judgment of the building element's properties. This feature reduces a great deal of effort of estimators.
4	Intelligent change management	If the design is changed, the next generation Construction Cost Estimation software can display changed, new, and deleted objects, and automatically update the quantities. The cost estimating can be easily adjusted. This feature helps the estimators to deal with the design change efficiently.
5	Export the standard cost estimating data	Export the standard IFC data file which include building element's dimensions, construction process and cost items data so that the downstream software, such as construction management software, information reuse software can directly use the data.

6. OPEN BIM DEVELOPMENTS

In order to achieve the above key requirements of cost modelling in the BIM environment, cost modelling software should be capable of implementing IFC interoperability, for which the vendors have to enable their software to read and write IFC format. This can be achieved through Information Delivery Manual (IDM) which defines the information exchanges between users, and Model View Definitions (MVDs) which define the implementations in software (buildingSMART, 2013d).

When user requirements for a data exchange are defined in an IDM and a solution that meets those requirements, through the use of software, is defined in a MVD, software vendors implement support for one or more specific MVDs in their software applications. After completing the implementations, the end user can use the data exchange defined in the IDM in their businesses (buildingSMART, 2013d).

According to the IFC Solution Factory (2013), it focuses on supporting the development and certification of IFC based data exchange in end user processes and software used in the worldwide construction industry. In order to accomplish this MVDs are developed by buildingSMART and other international organizations and they are made available for any software company to build support in their software. In addition, IFC Solution factory intents to provide information about software that has been certified for correct support of these MVDs.

Among various MVDS, Architectural Design to Quantity Takeoff for Cost Estimating, under the other international organizations MVDs, is the only MVD in the status of candidate for cost modelling. This MVD has completed its conceptual design which attempts to define a subset of the data created in architectural design software, which is useful for quantity take-off purposes. The basic idea behind this view is that design team members provide design object quantities which can be used as 'underlying quantities' that drive the calculation of 'construction quantities'. Designers think in terms of spaces, building elements and their functional properties. Quantity take-off focuses on assemblies, items, and the resources required constructing these assemblies (IFC Solution Factory, 2013).

The MVD development is based on the internationally agreed exchange levels of Quantity Take-Off (QTO) information. These levels are as shown below.

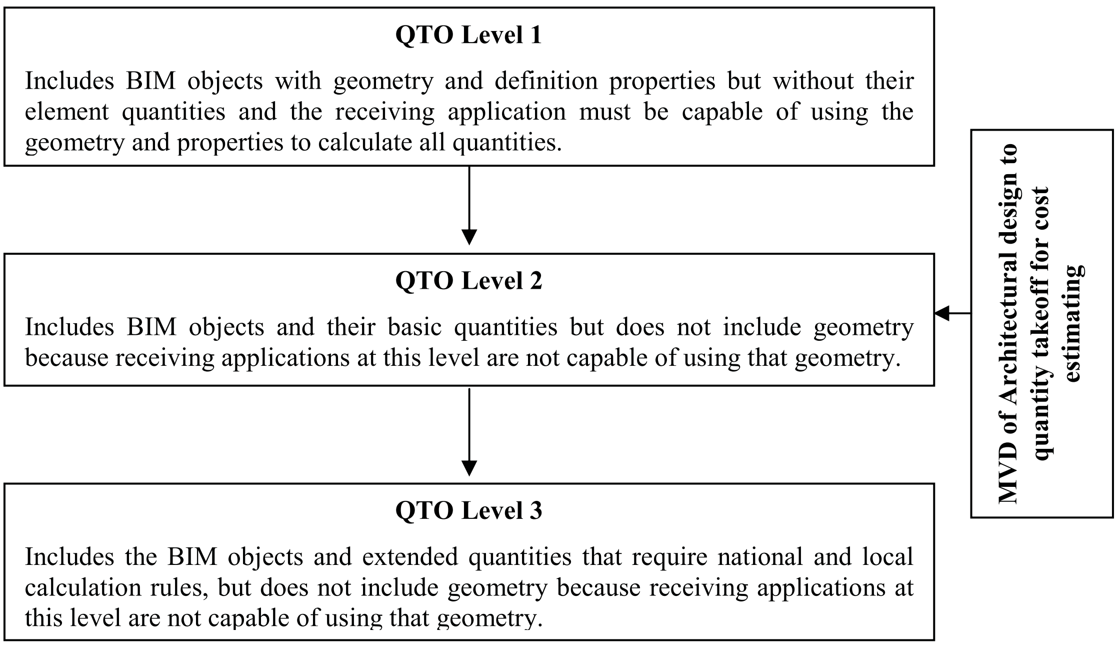

Figure 1: Levels of Exchange of QTO Information

In the scope definition of this MVD, it is clearly stated that most important cost modelling parameters like cost information and construction type libraries are not considered in this view.

7. CONCLUSIONS

As the conclusion of the literature findings of the ongoing research, it can be identified that in order to achieve the key requirements of the cost modelling in the BIM environment, interoperability through open standards is critical. It is mainly because; the main collaboration issues prevailing in the AEC projects should be addressed through the best practical approach, which is the open standard. Furthermore, the current Open BIM developments on cost estimation are not at a level where they could solve the issue of not having an integrated cost model in the BIM environment. Hence, developing a framework for integrated cost model comprising of the above mentioned key requirements in the BIM model is appearing to be a key requirement.

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THE RESHUFFLE OF CONTRACTUAL LIABILITIES BY IMPLEMENTING INTEGRATED PROJECT DELIVERY (IPD) IN BUILDING INFORMATION MODELLING (BIM) BASED CONSTRUCTION

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ABSTRACT

"Sustainability by building smarter", the vision of buildingSMART international clearly conveys what Building Information Modelling (BIM) was developed for. BIM has now been accepted as a primary tool for sustainable project procurement. Building information modelling (BIM) is the latest innovation of construction industry and it is increasingly becoming the design standard for architectural and construction engineering. Effective adoption of the BIM requires a change in the traditional work practices, where it needed a greater collaboration and communication among project participants and efficient flow of information. Conventional procurement methods are less efficient in delivering these requirements. The Integrated Project Delivery (IPD) approach is widely recognized as the most suitable project delivery approach to receive the full benefit of BIM adoption for construction project procurement. Basic concept of IPD is the collaboration among the owner, architect, and contractor to create the core team. The team focuses on trust, transparency, shared risk and reward, value-added decision making, and technology to complete a project as efficiently and effectively. Collaborative approaches to project procurement are very rare in Sri Lanka. A concept like IPD is totally a new paradigm for the local industry. Given the context that BIM is likely to become the standard in future and the widening global competition will force the local industry to adopt methods like IPD. This research is conducted to identify the reshuffle of contractual liabilities in IPD from those in traditional delivery method, where the findings will help the industry to get prepared to face future challenges.

Keywords: *Building Information Modelling, BIM, Contractual Liability, Integrated Project Delivery*

1. INTRODUCTION

Building Information Modelling (BIM) is one of main development technology that offers the potential increase of efficiency and effectiveness to construction projects. The collaborative environment needed for BIM procuring is offered from integrated project delivery (IPD) as an alliancing project delivery system. Although IPD is interpreted as beneficial to the design and construction industry, changing the industry into new relationships and methodologies could prove difficult. Implementing IPD create a reshuffle of contractual liabilities in traditional procurement. Knowledge on what and how liabilities are reshuffled is inevitable in achieving project success through these modern procurement options. Identifying whether reshuffle of contractual liabilities would occur by implementing IPD is the primary focus. If any significant reshuffle occurs, the study will further explore the extent of it. This is an ongoing research study conducted in Sri Lanka; and this paper presents the initial findings from its literature review.

2. BUILDING INFORMATION MODELLING

Society currently faces many challenges dealing with the current economic conditions and the pressing need to address climate change (and its effects) together with the wider sustainability agenda.

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Construction industry has found considerable practices to improve its efficiency and play a key role in addressing the environmental concerns. But construction has been widely recognized as an industry that exhibits many intractable problems. Information technology (IT) has been introducing new expectations to the industry as remedies and industry is currently making the transition to full digital model-based working, creating new opportunities and posing new challenges (Watson, 2011).

One of the latest technologies used in construction industry which has been introduced by IT sector is Building Information Model (BIM) (Qais Consulting [QC], 2010). A building information model is a digital representation of the physical and functional characteristics of a facility (Smith, 2007). In technical terms, BIM will be a transition from the traditional computer aided two-dimensional drawings to modelling representations of actual building parts and pieces used to build a structure. The use of three dimensional modelling will allow for the creation of a virtual model of an entire project (Udom, 2012).

The resulting model is a data-rich, object-oriented, intelligent and parametric digital representation of the facility. BIM helps to enable Architecture, Engineering and Construction (AEC) professionals and owners design, visualize, simulate, and analyze the key physical and functional characteristics of a project digitally before they build it. Using information within the model, everyone on the project team can make better, more-informed decisions across the entire project lifecycle of building and infrastructure projects (Hergunsel, 2011). Furthermore, in 2007, Stanford University's Center for Integrated Facilities Engineering showed that BIM provided a 40% reduction of unbudgeted changes; provided cost estimates within 3% of the traditional estimates; contract savings of up to 10% with the use of clash detection; and reduced project time by up to 7% (A buildingSMART alliance project, 2012).

The use of BIM by architects, engineers, contractors, owners, and others is rapidly becoming widespread within the design and construction industries (Wickersham, 2009). More recent experience indicates a trend in large clients and government agencies across the globe to mandate the use of BIM, not only for delivery of the building, but also as a tool to manage operationally. BIM adoption in the United States shows that almost 39% of the construction industry is now using BIM in major projects with separate design and construction procurement processes (Porwal and Hewage, 2012).

Although BIM can be used with all kinds of project delivery systems, including design / bid / build, many believe that its benefits are greatest when coupled with more collaborative approaches to project delivery (Wickersham, 2009).

3. INTEGRATED PROJECT DELIVERY

In the present, traditional procurement system has devolved into an adversarial process resulting in inefficiency, mistrust, and commoditization of services among owners, architects, contractors, subcontractors, and suppliers, each with their agendas, silos, and preferred outcomes built into the project delivery process (AIA and AGC of America, 2011). Relational contracts in construction procurement promote and facilitate construction activities through the principles of collaboration and lean project delivery to achieve project objectives in best way (Haynes *et al*., 2009). Therefore the industry has begun to look to more collaborative, non-traditional delivery systems to facilitate better communication, reduce/share risk, increase profits, and provide a positive experience for project participants. Integrated Project Delivery (IPD) is one of these collaborative systems (AIA and AGC of America, 2011).

IPD is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction (AIA California council and McGraw-Hill Construction, 2007). The parties intend that the project shall be delivered in a collaborative environment and shall endeavor to align individual interests with those of project. The parties agree to contribute their knowledge, skills and services during all phases of the project and to bring to bear their expertise for the benefit of project (AIA document C191™ 2009). Furthermore, IPD encourages early contribution of knowledge and experience and requires proactive involvement of key participants. Responsibility is placed on the most able person with decisions being made on a "best for project" basis (AIA California council and McGraw-Hill Construction, 2007).

AIA and AGC of America (2011) stated that, following contractual and behavioral principles of IPD;

Contractual Principles

- Key Participants Bound Together as Equals
- Shared Financial Risk and Reward Based on Project Outcome
- Liability Waivers between Key Participants
- Fiscal Transparency between Key Participants
- Early Involvement of Key Participants
- Jointly Developed Project Target Criteria
- Collaborative Decision Making

Behavioural Principles

- Mutual Respect and Trust
- Willingness to Collaborate
- Open Communication

3.1. TRADITIONAL PROJECT DELIVERY VS. INTEGRATED PROJECT DELIVERY

A comparison between the traditional project delivery method and IPD in terms of key features of a project delivery is presented in Table 1.

Table 1: Traditional vs. Integrated Project Delivery

Traditional Project Delivery		Integrated Project Delivery
Fragmented, assembled on "just-as-needed" or "minimum-necessary" basis, strongly hierarchical, controlled	teams	An integrated team entity composed key project stakeholders, assembled early in the process
Linear, distinct, segregated; knowledge gathered "just-as-needed"; information hoarded; silos of knowledge and expertise	process	Concurrent and multi-level; early contributions of knowledge and expertise; information openly shared; stakeholder trust and respect
Individually managed, transferred to the greatest extent possible	risk	Collectively managed, appropriately shared
Individually pursued; minimum effort for maximum return; (usually) first-cost based	compensation/ reward	Team success tied to project success; value-based
Paper-based, 2 dimensional; analogue	communications/ technology	Digitally based, virtual; Building Information Modelling
Encourage unilateral effort; allocate and transfer risk; no sharing	agreements	Encourage and support multi-lateral open sharing and collaboration; risk sharing

(Source: AIA and AIA California Council, 2007)

4. SIGNIFICANCE OF IPD IN BIM BASED CONSTRUCTION

BIM can be viewed as a virtual process that encompasses all aspects, disciplines, and systems of a facility within a single, virtual model, allowing all team members to collaborate more accurately and efficiently than traditional processes (Azhar, 2012). The successful implementation of BIM requires early involvement of all project stakeholders. It means that the traditional project delivery systems (e.g. design-bid-build) have very limited role in BIM-based projects. Recently the Integrated Project Delivery (IPD) concept emerges as a natural companion to BIM. IPD brings key construction management, trades, fabrication, supplier and product manufacturer expertise together with design professionals and the owner earlier in the process to produce a design that is optimized for quality, aesthetics, constructability, affordability, timeliness and seamless flow into lifecycle management (Azhar, 2012). In the United States, the IPD has become a preferred project delivery system for all major projects involving BIM (McGraw-Hill Construction, 2008).

5. CONTRACTUAL LIABILITIES IN TRADITIONAL PROJECT DELIVERY

There are several types of delivery methods in traditional project delivery Design-bid-build, Construction Manager at-Risk, and Design-Build are the three most commonly used traditional delivery methods. In each method, the roles of the design professional and contractor are clearly defined (Ballobin, 2008). Traditional contracting intends project participants operating within their own separate silos of responsibility (AIA National and AIACC, 2007). Generally, the architect or engineer is responsible for design, the contractor for construction means and methods (Ballobin, 2008).

6. CONTRACTUAL LIABILITIES IN BIM BASED IPD

Integrated Project Delivery (IPD) seeks to improve project outcomes through a collaborative approach of aligning the incentives and goals of the project team through shared risk and reward, early involvement of all parties, and a multi-party agreement (Gerber & Kent, 2010.). In its fullest version, IPD has given rise to new forms of contractual relations that dramatically change many of the current expectations of owners, architects, and construction managers (Wickersham, 2009). In a Project Alliance, the key participants collectively assume responsibility for agreed project performance. The shared opportunities and responsibilities align the parties' interests and provide an incentive for collaboration and blame-free performance (AIA National and AIA California Council, 2007). This is not to say, however, that IPD participants do not have separate work scopes for which they are primarily responsible. For the most part, the designers remain primarily responsible for design services and the constructors remain primarily responsible for construction services (Wickersham, 2009).

In a multi-party agreement (MPA), the primary project participants execute a single contract specifying their respective roles, rights, obligations, and liabilities. In effect, the multi-party agreement creates a temporary virtual, and in some instances formal, organization to realize a specific project. Because a single agreement is used, each party understands its role in relationship to the other participants. Multi-party agreements require trust, as compensation is tied to overall project success and individual success depends on the contributions of all team members. For a MPA to be successful, the participants must be committed to working as a team to achieve team goals (AIA National and AIA California Council, 2007).

7. POTENTIAL RESHUFFLE OF CONTRACTUAL LIABILITIES WITH INTRODUCTION OF IPD

In spite of the significant benefits associated with BIM, there are several legal issues and risks which the design and construction industry has not addressed properly (Simonian, 2013). Implement of all the functions available in a BIM system, presents a substantial set of legal issues (Sieminski, 2007). When implementing IPD, parties have to agree to a more innovative set of relationships and it raises important contractual issues that may not be addressed by standard industry contract forms (Wickersham, 2009).

One of issues IPD result of this approach is a blending of traditional roles. The blending of roles, while strengthening the creative process, can lead to the question of who is responsible for particular scopes of work. For that reason, a well-drafted IPD agreement clearly spells out individual work scopes (AIA National and AIA California Council, 2007).

8. Research Methodology

Not only has the absence of the IPD method, but also the rare knowledge about it in the Sri Lankan construction industry has posed challenges on developing an appropriate research methodology. Since direct empirical verification is not possible, a positivist approach to the research is not become suitable. Thus the researchers selected the alternative approach. For this research, it is assumed that contract documents represent the intentions of industry on the allocation of contractual liabilities among parties at various alternative procurement options. This assumption is unlikely to be found false because standard forms go through a rigorous process of review and refinements. The research will employ content analysis techniques to compare and contrast the allocation of contractual liabilities among parties in conventional practice and IPD set up by analysing standard forms of contract from each group. The researchers will interpret these documents during the analysis, and unclear contexts will be taken to industry experts for clarification where necessary. Thus the research entails interpretivist approach.

9. Conclusions

IPD is enabled and encouraged by recent developments in technology. Building Information Modelling (BIM) is one of main development technology that offers project managers and firm owners the potential to increase efficiency and create new opportunities. The collaborative environment needed for BIM procuring is offered from IPD as an alliancing project delivery system.

Traditional procurement system dominates in Sri Lankan construction industry even there are different non-traditional procurement systems introduced. Collaborative approaches to project procurement are very rare in Sri Lanka. A concept like IPD is totally a new hypothesis for the local industry. BIM is likely to become the standard in future and the widening global competition will force the local industry to adopt methods like IPD. When introducing integrated project delivery system to the Sri Lankan design and construction industry, changing the industry into new relationships and methodologies could prove difficult. Various and unaccustomed contractual liabilities of participants is one of main challenge caused when implementing IPD since it create a shuffle of contractual liabilities.

The absence of IPD method in Sri Lanka poses practical difficulties in adopting common research methods. An interpretivist approach to the research has been chosen to overcome those.

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THE RESHUFFLE OF RISKS FROM IMPLEMENTING BIM BASED INTEGRATED PROJECT DELIVERY IN SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

The shift from traditional procurement systems, towards more collaborative procurement systems which are backed-up with information and communication technology (ICT), is becoming the new trend in the present day construction industry around the world. Integrated Project Delivery (IPD) and Building Information Modelling (BIM) are the two most emerging and widely used systems to achieve this shift. These concepts are likely to be the new industry standard in the near future due to their collaborative nature, ability to implement sustainable procurement strategies, risk and reward sharing basis and high efficiency of construction by promoting dry construction. Yet, the Sri Lankan construction industry is still following the traditional rigid and highly separated procurement systems with traditional 2D computer aided drafting (CAD). Therefore adopting and continuing BIM and IPD will generate many issues and risks since the industry is used to the absolute opposite of the underlying principles of both BIM and IPD. Under this context, a research is conducted with a broader aim of identifying the potential reshuffle of risks, which a construction project in Sri Lanka would be subjected, if it is delivered through BIM based IPD. This paper contains the preliminary findings of a literature review conducted on the current risks the industry faces and on identifying the requisites of BIM and IPD.

Keywords: *Building Information Modelling (BIM); Integrated Project Delivery (IPD); Risks; Sri Lanka; Sustainability.*

1. INTRODUCTION

Integrated Project Delivery (IPD) and Building Information Modelling (BIM) are modern day concepts that have revolutionized the way construction industry behaves. These two concepts are interrelated and need each other to produce a successful construction project (American Institute of Architects, National [AIA National] and McGrow-Hill, 2007; American Institute of Architects California Council [AIACC], 2007). Sri Lankan construction industry's procurement system is rooted on conventional procurement methods, while both designing and construction is still largely based upon 2D CAD drawings. Therefore adopting a highly technical ICT tool such as BIM and a highly collaborative procurement method such as IPD will be, challenging. This research is aimed at identifying the potential reshuffle of risks which a construction project in Sri Lanka would be subjected, if it is delivered through BIM based IPD.

2. INTEGRATED PROJECT DELIVERY

IPD is a collaborative project delivery method that has been developed for the construction industry. IPD is based on cross-functional project teams who are collaborating on a building's design and construction and, lifecycle management for optimized owner outcomes using model-based technology as a platform (Autodesk, 2008).

McKeon, (as cited in Jayasena and Senevirathna, 2012) states that the concept of IPD was created by a group of businessmen from Orland and Florida in 1990's. They had found that the new concept is very effective in serving the owner in a better manner and further reported cost savings and less stress

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during working. This had motivated them to work together for about five years and trademark the system in 2005.

AIA National and AIACC are two joint professional bodies which practice IPD. AIA National and AIACC (2007) define;

> IPD is a project delivery approach that integrates people, systems, business structures, and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction.

Basically, IPD is a value based project delivery method. This value base is built on collaboration which in turn is built on trust, where all the key participants and their teams work together as they are part of one organization. They are bound by a well structured and trust based collaborative contract agreement and work with the intention of delivering a successful project rather than focusing on individual goals (AIA National and AIACC, 2007; Ashcraft, 2010).

2.1. PRINCIPLES OF IPD

IPD system is driven by a set of unique principles which allows the project stakeholders to acquire better outcomes. IPD expect the people who are delivering the project to adhere to these principles. Thus, by adhering to these principles only, a better outcome can be expected. Table 1 excerpted from the IPD Guide published by the AIA National and AIACC (2007) explains these key principles.

Table 1: Principles of IPD

Principle	Explanation
Mutual Respect and Trust	Owner, designer, consultants, constructor, subcontractors and suppliers understand the value of collaboration and are committed to working as a team in the best interests of the project.
Mutual Benefit and Reward	All participants or team members benefit from IPD. Since the integrated process requires early involvement by more parties, IPD compensation structures recognize and reward early involvement. Compensation is based on the value added by an organization and it rewards “what’s best for project” behaviour, such as by providing incentives tied to achieving project goals. Integrated projects use innovative business models to support collaboration and efficiency.
Collaborative Innovation and Decision Making	Innovation is stimulated when ideas are freely exchanged among all participants. In an integrated project, ideas are judged on their merits, not on the author’s role or status. Key decisions are evaluated by the project team and, to the greatest practical extent, made unanimously.
Early Involvement of Key Participants	Key participants are involved from the earliest practical moment. Decision making is improved by the influx of knowledge and expertise of all key participants. Their combined knowledge and expertise is most powerful during the project’s early stages where informed decisions have the greatest effect.
Early Goal Definition	Project goals are developed early, agreed upon and respected by all participants. Insight from each participant is valued in a culture that promotes and drives innovation and outstanding performance, holding project outcomes at the centre within a framework of individual participant objectives and values.
Intensified Planning	The IPD approach recognizes that, increased effort in planning results in increased efficiency and savings during execution. Thus the thrust of the integrated approach is not to reduce design effort, but rather to greatly improve the design results, streamlining and shortening the much more expensive construction effort.
Open Communication	IPD’s focus on team performance is based on open, direct, and honest communication among all participants. Responsibilities are clearly defined in a no-blame culture leading to identification and resolution of problems, not determination of liability. Disputes are recognized as they occur and promptly resolved.

Principle	Explanation
Appropriate Technology	Integrated projects often rely on cutting edge technologies. Technologies are specified at project initiation to maximize functionality, generality and interoperability. Open and interoperable data exchanges based on disciplined and transparent data structures are essential to support IPD. Because open standards best enable communications among all participants, technology that is compliant with open standards is used whenever available.
Organization and Leadership	The project team is an organization in its own right and all team members are committed to the project team's goals and values. Leadership is taken by the team member most capable with regard to specific work and services. Often, design professionals and contractors lead in areas of their traditional competence with support from the entire team. However specific roles are necessarily determined on a project-by-project basis. Roles are clearly defined, without creating artificial barriers that chill open communication and risk taking.

Source: Integrated Project Delivery (A Guide by AIA National and AIACC, 2007)

2.2. *COMPARISON OF IPD WITH TRADITIONAL PROJECT DELIVERY*

Traditional project delivery methods have many shortcomings since stakeholders focus on fragmented work scenarios and individual achievement rather than project goals. Hence the IPD system is created to remove all those shortcomings to make a win-win situation for all the participants. Table 2 excerpted from the IPD Guide published by AIA National and AIACC (2007) contains the key differences between the traditional project delivery methods and IPD.

Table 2: Key Differences between Traditional Project Delivery and IPD

Traditional		IPD
Fragmented, assembled on "just-as-needed" or "minimum-necessary" basis, strongly hierarchical, controlled	Teams	An integrated team entity composed key project stakeholders, assembled early in the process, open, collaborative
Linear, distinct, segregated; knowledge gathered "just-as-needed"; information hoarded; silos of knowledge and expertise	Process	Concurrent and multi-level; early contributions of knowledge and expertise; information openly shared; stakeholder trust and respect
Individually managed, transferred to the greatest extent possible	Risk	Collectively managed, appropriately shared
Individually pursued; minimum effort for maximum return; (usually) first-cost based	Compensation/ Reward	Team success tied to project success; value-based
Paper-based, 2 dimensional; analogue	Communication/ Technology	Digitally based, virtual; Building Information Modelling (3, 4 and 5 dimensional)
Encourage unilateral effort; allocate and transfer risk; no sharing	Agreements	Encourage, foster, promote and support multi-lateral open sharing and collaboration; risk sharing

Source: Integrated Project Delivery (A Guide by AIA National and AIACC, 2007)

3. BUILDING INFORMATION MODELLING

Building Information Modelling (BIM) is the process of creating a digital parametric model which represents the physical and functional characteristic of a building in full detail. BIM creates a shared knowledge pool which can be used to form reliable decisions during the design, construction phases and throughout the life cycle of the facility (Eastman *et al.*, 2011; BuildingSMART, 2012; Jayasena and Weddikkara, 2012). Furthermore this integration of information allows the various participants to the contract, to exchange information easily (Eastman *et al.*, 2011).

BIM is not a specific software itself. Yet, is an IT solution for integrating software applications. To achieve integration, the software are created with a standard data terminology called International Framework for Dictionaries (IFD) which defines the framework for development of data for BIM technology and Industry Foundation Classes (IFC) which defines the data exchange format. Therefore different software need to be interoperable with each other for them to be used in a BIM framework (Jayasena and Weddikkara, 2012; Wong and Fan, 2013).

One important object of implementing BIM is to promote sustainable construction. This is achieved by promoting dry construction rather than wet construction allowing the project to reduce construction waste including energy waste and reducing environmental damage (Wong and Fan, 2013). This is achieved by defining properties and behavioural relationships between each object within the BIM model which makes these objects "intelligent" (Jayasena and Weddikkara, 2012). Therefore each object knows its function and how it should relate with the other objects. This makes a complete computer generated model which contains precise geometry and data which are needed to support the construction, fabrication, and procurement activities (Eastman *et al*., 2011).

While implementing a platform for software interoperability, BIM encourages high level of information sharing as well. Industry is used to work with different software applications which are usually incompatible with each other. However, BIM requires a major shift from working separately to working in a common platform (one common model), within a highly collaborative environment where people will have to interact more and exchange data for the benefit of the project (Pittard, 2013).

4. OVERVIEW ON CONSTRUCTION RISKS

Although risk is an inherent component in every endeavour humans undertake, the success or failure of any venture depend on the method that is used to deal with the risk. Yet, the construction industry and its stakeholders, mainly clients, contractors and the public, has suffered throughout the history due to the industry's failure to manage risk and meet time and cost targets (Thompson and Perry, 1998).

There are many different definitions by different authors on Risk in literature. According to Kartam and Kartam (2001), risk has been defined as the probability of occurrence of some uncertain, unpredictable and even undesirable event(s) that would change the prospects for the profitability on a given investment. Amaraekara (2009) emphasized risk as the uncertainty of loss, in a seminar on Construction Risks and Insurance at the Institute for Construction Training and Development (ICTAD) of Sri Lanka. The author further elaborates it as follows.

Risk = Hazard x Probability of Occurrence

According to the author this formula is to be used when the hazard is measured in terms of severity. Thus the probability of occurrence of a catastrophic hazard is extremely low; the risk may still be acceptable, whereas if the probability of a marginal hazard is extremely high, the risk may not be acceptable.

For a certain risk to exist there is a need of a cause or a source. The source of risks in the construction industry is the very nature of the industry itself, types of business and the environment (Kartam and Kartam, 2001). According to Thompson and Perry (1998), the inherent nature of the industry, which is, the size of the product, complexity of the process, speed of construction, location (geographical location), familiarity with the type of work, political planning and commercial planning creates these risks.

5. NEED FOR BIM BASED INTEGRATED PROJECT DELIVERY FOR CONSTRUCTION INDUSTRY

Current Sri Lankan construction industry faces many difficulties since it is driven by the traditional procurement system. Lack of trust between the key participants, the dominant figure held by the consultants (Gunathilaka and Jayasena, 2008; Osipova and Eriksson, 2012), and design variations during construction period are some key difficulties while miscommunication between key parties adds fuel to these major problems. It is inevitable in the traditional procurement structure to reduce miscommunication since each stakeholder makes adjustments to his part of the project since they work largely in isolation (Wong and Fan, 2013). This leads towards the antagonistic relationship which is the root cause of disputes, cost and time overruns that plague the present day industry (AIA National and AIACC, 2007). Hence, there is a need of a well structured collaborative project delivery method for the industry.

The importance of the integrated construction project delivery, backed up with IT solutions for information exchange, had been identified by many authors throughout the literature as well as through industry surveys in recent times. Autodesk (2008) comment that, "Within the building industry there is a growing interest in IPD and the role of BIM in promoting integration among building professionals and improving design outcomes". They have derived this conclusion in the whitepaper published in 2008 as a result of doing a series of roundtable discussions throughout North America on the subject of IPD.

AIA National and AIACC have commented on the importance of IT based collaborative project delivery as well. The IPD guide by AIA National and AIACC (2007) states that, as a result of early collaboration and the use of BIM technology, more integrated, interactive, virtual approach to building design and operation is emerging. Furthermore a study conducted by the National Institute of Standards and Technology (NIST) of the USA from 2004, revealed that lack of AEC software interoperability is costing the industry \$15.8 Billion annually (AIA National and AIACC, 2007).

Integrating IPD and BIM is a strong tool in implementing lean construction and achieving sustainability. The United Kingdom's Office of Government Commerce (UKOGC) has estimated that, savings of up to 30% in the construction cost can be achieved where integrated teams promote continuous improvement over a series of construction projects. UKOGC had further estimated that a single project employing integrated supply teams can achieve savings from 2% to 10% (AIA National and AIACC, 2007). Furthermore the importance of integrated processes has been acknowledged by sustainable rating systems such as LEED and ASHRAE in their new energy codes (AIA National and AIACC, 2007).

Proper project integration is vital to achieve the best outcome in the construction industry. Baiden and Price (2011) defines integration of project teams as "where different disciplines or organizations with different goals, needs and cultures merge into a single cohesive and mutually supporting unit with collaborative alignment of processes and cultures". They further emphasize that, when it comes to construction, this integration often refers to the collaborative working practices, methods and behaviours that promote an environment where information is freely exchanged among the various parties.

6. UNDERSTANDING PREVAILING RISKS IN THE CONSTRUCTION INDUSTRY

A construction project faces risks throughout the life of the project. Yet the greatest uncertainty of the project is in the earliest stages. Earliest stages of the project are when decisions with the greatest impact are made (Thompson and Perry, 1998). However, the client should bear all the risks, unless transferred to another party for fair compensation (Kartam and Kartam, 2001).

There are many categorizations of risks relating to the construction industry in the literature. One such is emphasised by Kartam and Kartam (2001) in their study on the Kuwaiti construction industry as physical, environmental, design, logistics, financial, legal, political, construction and operation risks.

Bunni (2009) has divided construction risks into major categories, considering the time of occurrence (chronology) and the nature of the risks. The author had further explained a whole variety of risks that can happen during each category.

Table 3 summarises the major risks in the construction industry that are explained by Bunni (2009) and by other authors in the existing literature.

Table 3: Existing Construction Risks Excerpted from Existing Literature

Classification	Risks
Feasibility stage	Procurement risks Identifying of client requirements Choice of site Inadequacy of soil investigation, surveys and site investigation Inadequacy of finance Inaccurate cost estimation (Osipova and Eriksson, 2012) Permits and regulations (Kartam and Kartam, 2001)
Design stage	Negligence, lack of care and failure to take account of foreseeable problems and work done in haste Inappropriate choice of design Lack of knowledge on basics and of state of the art technology Poor communication Adversarial relationship between consultants (Gunathilaka and Jayasena, 2008) Price-based selection of builders (Gunathilaka and Jayasena, 2008)
During construction, associated with the project and the location	Acts of god Resource availability (Kartam and Kartam, 2001) Inflation and unanticipated price changes (Kartam and Kartam, 2001; Kuganesan, 2007) War threats (Kartam and Kartam, 2001) Poor coordination with sub contractors (Kartam and Kartam, 2001) Financial instability Stability of the government Legislative changes Delays in site availability and issues with access to site (Amarasekara, 2009)
During construction, associated with the nature of the site	Acts of god Topographical and geological issues Underground obstructions Unforeseen physical obstructions
During construction, associated with the technical aspects of the project	Construction time overrun Technical complexity and innovation of new techniques Defective construction (Kartam and Kartam, 2001) Defective material and dangerous substances Defective or early removal of temporary work or supports Corrosion, collapse, vibration, oscillation and subsidence Inadequate site management Defective design Late material deliveries (Amarasekara, 2009) Sub contractors failure to perform (Amarasekara, 2009)
During construction associated with acts of man	Negligence, lack of care and inadequate supervision Conflicts leading to disputes Variations and extra work Lack of communication and poor programming of work Health and safety issues Fraud, theft, burglary, arson, riots, civil commotion and strikes Dominant figure of the consultant (Gunathilaka and Jayasena, 2008)
Post-construction stage	Damages (Amarasekara, 2009) Durability, serviceability and fitness for purpose issues Operational issues of elements Poor resistance to fire and other hazards

7. RISK ALLOCATION APPROACHES IN THE PRESENT SRI LANKAN CONSTRUCTION INDUSTRY

Traditional procurement approach still plays the major role of procurement within the Sri Lankan construction industry. This approach has created a highly fragmented nature in the industry environment where parties to the contract act as rivals (Gunathilaka and Jayasena, 2008). This has caused the functions done by each party to become fragmented as well, although each function is critical to be connected to each other in order to finish a construction project successfully. This has caused the construction professionals to highly depend on the conditions of contract, in order to solve every construction related issue.

Although construction risks are a responsibility of the client in general (Kartam and Kartam, 2001), the Sri Lankan procurement system is fixed in a manner which passes a majority of the risks to the shoulder of the builder. The builder is responsible to obtain a separate Insurance policy for each project such as Contractor's All Risk policy. Although the costs incurred during obtaining insurance policies and costs related to having an insurance policy (premium) are covered through the contract sum, the contractor is responsible to mitigate all kinds of risks that may happen inside the site.

Therefore the contractors have to decide risk management strategies including aspects such as risk responsibility, risk patterns and risk management capabilities. In managing these risk strategies main contractors even tend to pass the responsibility of certain risks such as quality of material and workmanship to subcontractors as well (Perera *et al.*, 2008). Due to this factor contractors and sub contractors sometimes tend to input high contingency values to the contract sum which makes the contract sum rather high. However there is some sharing of risks by the client and the contractor when it comes to uninsurable risks and bureaucratic delays (Amarasekara, 2009).

8. RISK ALLOCATION APPROACHES IN BIM BASED IPD SYSTEM

Since BIM is a tool which is used in designing, majority of the risk allocation structure lies with the IPD framework itself. One of the principles of IPD is "Mutual Benefit and Reward" which is about "Sharing Risks and Sharing Benefits" (AIA National and AIACC, 2007). IPD agreements include participants agreeing to place all or a part of the participants' profit to a risk pool that is augmented if the project performance is met or exceeded. This will be used to cover the cost overruns if the project goals are not met. This makes the key participants to the project to share any risk that will happen during the different stages of the project. Furthermore the individual profit under IPD agreement is not about fulfilling one's own work scope, amount of work performed or about individual performance. Hence the individual profit is a proportionate amount to the overall project success (Ashcraft, 2010; Cleves, 2011).

An agreement to share the risks and rewards helps to discourage selfish actions by individuals as well. Therefore every participant to the contract will be fully committed to do the project as it is expected to be (HansonBridgett, 2010).

Liability waiver concept is another strong point of IPD as IPD discourages going forward with any dispute resolution mechanism. Selecting a dispute resolution method as a mean of escape is always an indication of lack of trust. Therefore parties agree to waive any claim against each other except for wilful defaults (AIA National and AIACC, 2007). In order to compensate this, an assessment to quantify the potential risks can be done prior signing the IPD agreement and including an allowance in the project cost. Each party can do this assessment and allocation of a sum to the project cost (Ashcraft, 2010). Though a contingency is applied an actual saving of monetary terms will be there, since liability waiving reduces the costs related to dispute resolution (Ashcraft, 2010).

It should be noted that the IPD system is made in a manner that every key participant (owner, architect, engineers, contractor, cost consultants and other professionals) to the contract get involved in the project at the project initiating stage. This makes every participant to be a part of the decision making process where every decision is taken by collaborating with each other. This makes every participant liable for project risks as well.

9. Government and Industry's Role in Promoting Collaborative Work Practices

Sri Lankan government's usage of the traditional procurement system as its prime method for a long time has acted as a major contributing factor for the industry to hold on to the traditional system and to believe it as the only possible way of working in the industry. Therefore, the industry has somewhat become saturated, though it has a great potential to achieve better development (Gunathilaka and Jayasena, 2008; Rameezdeen and Silva, 2002).

Collaborative work practices are not something that is technical and need special scientific methods. Hence it is something psychological and can be achieved through respect, understanding, good communication and giving priority to project goals rather than individual goals (Rameezdeen and Silva, 2002; AIA National and AIACC, 2007). These are the very aspects that is lacking in the industry.

Promoting collaborative work practices can be initiated by any level in the industry; either by government sector, private sector or even the academic sector. Only catalyst that is needed to initiate this is, a new way of thinking, which will lead the way for the professionals to wanting to get out of the hardships and conflicts that they face due to the traditional system.

However once initiated, the government officials and statutory bodies have the responsibility of developing new strategies and help promote it throughout the industry. This can be achieved specially by developing new standards (standard documentation) and help the academics invent new ways of further developing the system. However the promotion and adoption of the system purely depend on the professionals' attitude of welcoming it. This factor equally affects the creation of new standards and regulations as well. However, the present era is the perfect time to adopt collaborative practices, since the Sri Lanka government is promoting development throughout the island.

10. Conclusions

Construction industry in any country is a complex and high-risk sector which is dominated by traditional contracts. Construction industry has a direct impact on the national economy and is generally used as an indicator for economic well being of the country. Yet the industry is criticised for failing to meet the demands of the modern business environment, low profitability levels, low productivity levels, using outdated technology and failing in the competitive international market. The main reason behind these has been identified as the traditional procurement systems and their limitations which the local industry is still using as its primary system (Gunathilaka and Jayasena, 2008).

There are many instances in the literature where the importance of a different but more collaborative procurement system has been identified. Yet the Sri Lankan industry doesn't practice collaborative procurement strategies such as partnering (Jayasena and Senevirathne, 2012) and hardly use state of the art technology for designing and constructing (Jayasena and Weddikkara, 2012). Jayasena and Weddikkara, (2012) further explained that, it would not be a challenge to adopt BIM technology since the country has comparatively high IT literacy and Architecture, Engineering and Construction (AEC) professionals with fair computer knowledge. Yet, they suggested that the challenge of introducing BIM would rather arise a resistance to change due to overlapping of professional boundaries. Researchers have further identified that contractors in general, are more supportive towards the adaption of collaborative practices and technological practices, and to shift from the traditional procurement system towards relational contracting (Gunathilaka and Jayasena, 2008).

As described above in the previous sections, the Sri Lankan construction industry is exactly the opposite to the fundamental principles of BIM and IPD concepts. Most importantly the IPD's principle of risk sharing is a totally new concept to the local industry since the industry is used to passing the risk towards the contractor. Even the local insurance schemas have been developed under the basis that contractor bears all the risks.

Therefore any transition from traditional procurement system to a highly collaborative and highly technical procurement approach such as BIM based IPD will certainly be a risk shifting factor in the local industry which would lead to a change in the very way people look at construction risks and to define and create new risk transferring and risk mitigation methods.

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USE OF RECYCLE PAPER MILL RESIDUE AND FLY ASH IN PRODUCTION OF WASTE-CREATE BRICKS

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ABSTRACT

Accumulation of unmanaged industrial solid waste, especially in developing countries has resulted in an increased environmental concern. Resource recovery and utilization of industrial by-product materials for making construction material has gained significant attention across the world. In this research study, recycle paper mill residue (RPMR) and fly ash (FA) are utilized to improve the properties of bricks. This research study evaluated the feasibility of utilizing RPMR and FA for making construction bricks. A homogeneous mixture of RPMR-FA-cement was prepared with fixed content of RPMR (50% by weight) and varying amount of FA (30-50% by weight) and cement (0-20% by weight). The waste-create bricks were developed from the homogeneous mixture of RPMR-FA-cement and tested in accordance with the IS codes. Characterization of RPMR and FA was performed. The SEM monographs show that RPMR has a porous and fibrous structure. The TG-DTA characterization demonstrated that RPMR can withstand temperatures up to 280 ^{o}C. The results indicate that RPMR- bricks prepared from RPMR-FA-cement combination are light weight and meet compressive strength requirements of IS 1077-1992. This novel construction material serves objectives of resource recovery through prudent solid waste management.

Keywords: *Compressive Strength; Fly Ash; Recycle Paper Mill Residue; Waste-Create Brick.*

1. INTRODUCTION

Brick is one of the important materials for construction industry. The conventional method of manufacturing bricks has left this important material aloof in advancement. The infrastructure such as buildings for housing and industry, and the facilities for handling water and sewage requires large amounts of construction materials. Since the large demand has been placed on building material industry especially in the last decade owing to the increasing population, there is a mismatch between demand-supply management of these materials. Hence to meet the continuously increasing demand, researchers are attempting to design and develop sustainable alternative solutions for the construction material. The increase in the popularity of using environmental friendly, low cost and lightweight construction materials in building industry has brought about the need to investigate how this can be achieved by benefiting to the environment as well as maintaining the material requirements affirmed in the standards. Brick is one of the most accommodating masonry units as a building material due to its properties. Attempts have been made to incorporate waste in the production of bricks (Raut et al., 2011). Thermal conductivity can be reduced by addition of pore-forming agents (waste material) to the bricks before firing (Dondi *et al.,* 1997). Another advantage of lightweight bricks is reduced transportation costs (Hauck et al., 1998). The cementitious binder, fly ash-lime-gypsum (FaL-G), finds extensive application in the manufacturing of building components and materials such as bricks, hollow bricks and structural concretes (Singh and Garg, 1997). The by-products and residues from pulp and paper industry are managed using several approaches including land filling, incineration, use

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in cement plant and brickworks, agricultural use and composting, anaerobic treatment, recycling and others (Huet, 1982). The needs to conserve traditional building materials that are facing depletion have obliged engineers to look for alternative materials (Abang and Chandra, 1977). The developed porous and lightweight bricks with reduced thermal conductivity and acceptable compressive strength by using paper processing residues as an additive to earthenware brick to produce the pores. Chemical analysis of the paper waste and brick raw material was performed. Mixtures containing brick raw materials and the paper waste were prepared at different proportions (up to 30% by weight). The granulated powder mixtures were compressed in a hydraulic press, and the green bodies were dried before firing at 1100 0C (Mucahit and Sedat, 2009). Physico-mechanical properties such as density, strength, thermal conductivity and leachate characteristics of fired clay bricks manufactured with different percentages of cigarate butts were investigated and analysed (Aeslina *et al.,* 2010). The possible uses of the recycled slag of welding flux (SWF) was analysed in the civil construction. It was investigated the liability of SWF as substitute of sand in the production of multiple- use mortars and clay for the production of ceramic bricks (Caroline *et al.,* 2009). The manufacturing of high strength building bricks and blocks of precise dimensions and desired properties such as lacking brittleness, having energy absorbing ability, being lightweight, shock proof and having the property of thermal insulation and sound absorption from cellulosic product recycle industry waste (CPRIW) and, fibrous cellulosic product processing industry waste (FCOOIW) were investigated (Mandavgane and Ralegaonkar, 2009). Recycling of such wastes by incorporating them into building materials is a practical solution to the pollution problem.

The present paper focuses on development of waste-create bricks using RPMR-cement combination which are useful for the sustainable development of construction industry. The low cost hand operated mixing and moulding machinery has been designed and fabricated. Optimal composition of the waste-create blocks with respect to RPMR-FA-cement has been determined for various proportions by evaluating the properties. The Indian standards recommended all the performance testes have been carried out on the waste-create bricks.

2. Materials And Methods

Recycle paper mill residue (RPMR) was obtained from M/s Madhyapradesh Paper mill, Nagpur, India and fly ash was collected from thermal power station khaperkheda, Nagpur. The paper mill mainly works in recycling the newspaper waste. The RPMR thus obtained was used for making building blocks by mixing fly ash with Portland cement in different weight proportions. Ordinary Portland cement (43- grade) confirming to Bureau of Indian Standard (BIS), IS: 12269 were used.

2.1. Characterization of RPMR and FA

Chemical analysis of RPMR and FA brick raw material was done by using Energy Dispersive X-ray Fluorescence Spectrometer (XRF, Philips, PW 1840). Proximate and ultimate analysis of RPMR was carried out using gravimetric methods. Thermo-gravimetric-differential thermal analysis (TG-DTA) (Mettler, TA 4000) was carried out to determine the thermal stability. Scanning electron micrograph photographs have been recorded using JEOL Model No. JXA – 840 A, Japan.

2.2. Mixing and Fabrication of Bricks

Hand operated hydraulic press (Figure 1) was used to make bricks of dimensions 230x105x80 mm^3. The mixes of RPMR, fly ash and cement with different compositions were prepared. RPMR weight percentage in the composition mix was fixed at 50 %. The details of the mix are given in Table 1. The different mix compositions were prepared with uniform consistency for all the samples. 60 samples each of composition (RPMR: FA: Cement) C0 (50:50:0), C5 (50:45:5), C10 (50:40: 10), C15 (50:35:15), C20 (50:30:20) were prepared.

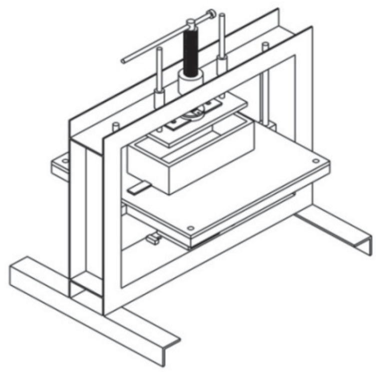

Figure 1: Design of Mould for Making Bricks Using RPMR- FA-Cement Mix

Table 1: Details of Composition

Sample Name (RPMR: FA: Cement)	Weight of RPMR (kg)	Weight of Fly Ash (kg)	Weight of Cement (kg)
C0(50:50:00)	35	35	0
C5(50:45:05)	35	31.5	3.5
C10(50:40:10)	35	28	7.0
C15(50:35:15)	35	24.5	10.5
C20(50:30:20)	35	21	14

In the mixing process of samples, RPMR fly ash and cement contents were placed in a specially designed and fabricated mixer (Figure 2) and mixed for 2 min. RPMR being fibrous in nature and lumpy, the blades of the mixer are designed to shear the RPMR mass every time it rotates. It was observed that RPMR is uniformly scattered within the mixes forming a homogeneous mixture with cement. In order to obtain more homogeneous mixes, the water was sprayed by air pump onto the mixes while the mixer is turning. Another 5 min. of mixing was conducted. Afterward, the fresh mixes are fed into the steel moulds (Figure 1). The top of the mould had uniform perforation size 3mm to let ooze moisture. The mix was pressed in the mould till 25±4% of its initial moisture was removed. The brick was taken out and kept for solar drying till its moisture further reduces by another 15±3%. The semi-dried brick was further pressed till its moisture content is reduced by 10±2% and then kept for final sun drying. As RPMR is fibrous in nature, holds moisture inside and do not let loose it easily. It was observed that if bricks were made in single stage, on drying the brick surface becomes irregular and uneven. This is because, when the bricks are made under high pressure in single stage, the pressure distribution inside the core of brick and on the surface is same and very high. As the wet bricks are solar dried, moisture from the surface evaporates developing a concentration difference of moisture between core and surface. On account of the driving force moisture at original high pressure, travels from the core to the surface. There exists pressure gradient too between the core and the surface. When the pressured moisture reaches the surface it deforms the surface and makes it irregular. Hence to keep the surface smooth on drying, the bricks are made in two stage operations.

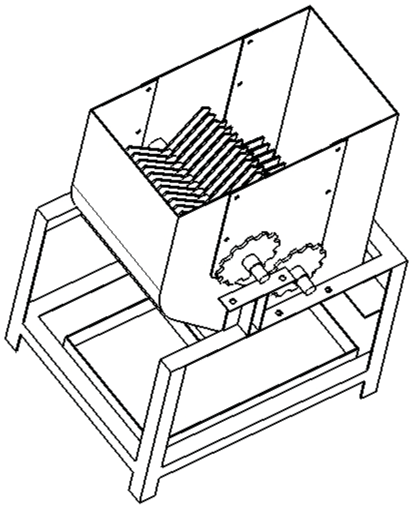

Figure 2: Design of Mixture for Mixing RPMR, FA and Cement

3. TEST METHODS

The series of tests were carried out according to IS 3495 (Part 1 to 4): 1992 to determine compressive strength, water absorption, specific weight, voidage and Efflorescence. The compressive strength was determined in a Universal Testing Machine (UTM) as per IS 3495 (Part 1):1992. For various percentages of sludge, three samples were made and subjected to a compressive strength test after complete drying, and the average strengths were obtained.

4. RESULTS AND DISCUSSION

4.1. CHARACTERIZATION OF RPMR AND FA

RPMR and FA mainly contains Si (60%) (Table 2a and 2b) depicting the XRF scan data. Table 3 gives the proximate analysis and Table 4 presents ultimate analysis.

Table 2a: Elemental Analysis of RPMR

O %	Ca %	Si %	Al %	Mg %	S %	Ti %	K %	Fe %	Na %	Cu %	P %	Cl %
15.83	14.94	60.57	2.06	3.59	1.07	0.15	0.16	0.92	0.22	0.05	0.03	0.41

Table 2b: Elemental Analysis of FA

Na_2O %	CaO %	SiO_2 %	Al_2O_3 %	MgO %	SO_3 %	TiO_2 %	K_2O %	Fe_2O_3 %	MnO %	CuO %	PbO %	Cl %
0.20	0.66	59.57	31.27	0.43	0.15	1.81	0.89	3.92	0.03	0.009	0.008	0.007

Table 3: Proximate Analysis of RPMR

Sr. No.	Wt. in grams	Moist %	Ash %	Volatile Materials %	Free Carbon %	GCV Kcal/kg
1.	420	5.8	40.6	44.7	8.9	2372

Table 4: Ultimate Analysis of RPMR

Sr. No.	Wt. in grams	C %	H %	N %	S %	O %
1.	420	22.7	2.5	0.3	0.4	23.6

According to the TG curves (Figure 3) of RPMR samples have not been thermally pre-treated and the mass loss of 45% occurs between 290 and 300^{0}C. This curve reveals the appearance of three distinct mass loss regions. The first loss (7.5%), between 30 and 280^{0}C, is attributed to the removal of superficial water molecules or water from the solid pores. At second mass loss the material get thermally degraded and get sintered. Thus, the bricks made out of RPMR can withstand maximum of 300^{0}C.

SEM images (Figure 4) for RPMR clearly indicate the presence of irregular pores and fibrous nature. The RPMR holds the moisture in these pores and the fibrous envelops providing obstacle for moisture to move towards the surface. Fibrous nature gives very high energy absorbing ability and hence the high compressive strength.

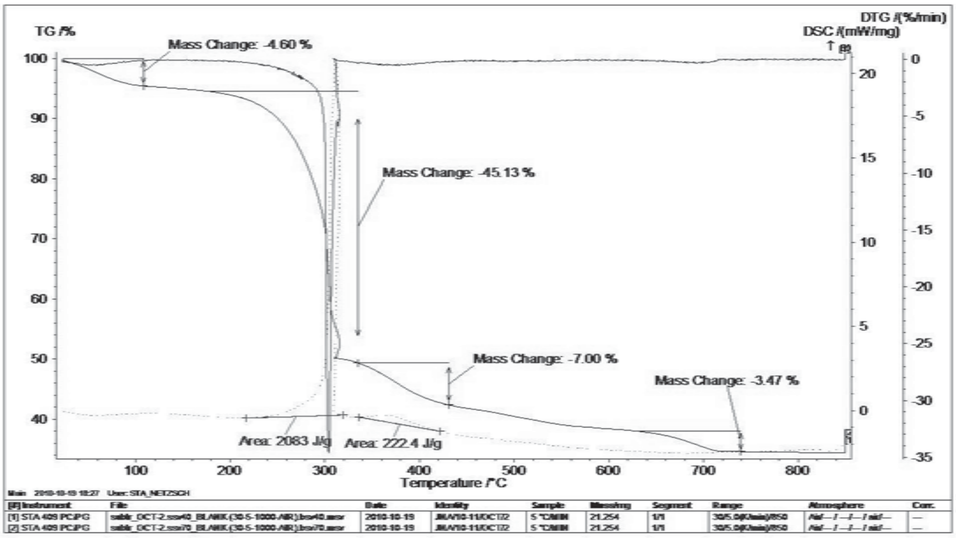

Figure 3: TG-DTA of RPMR

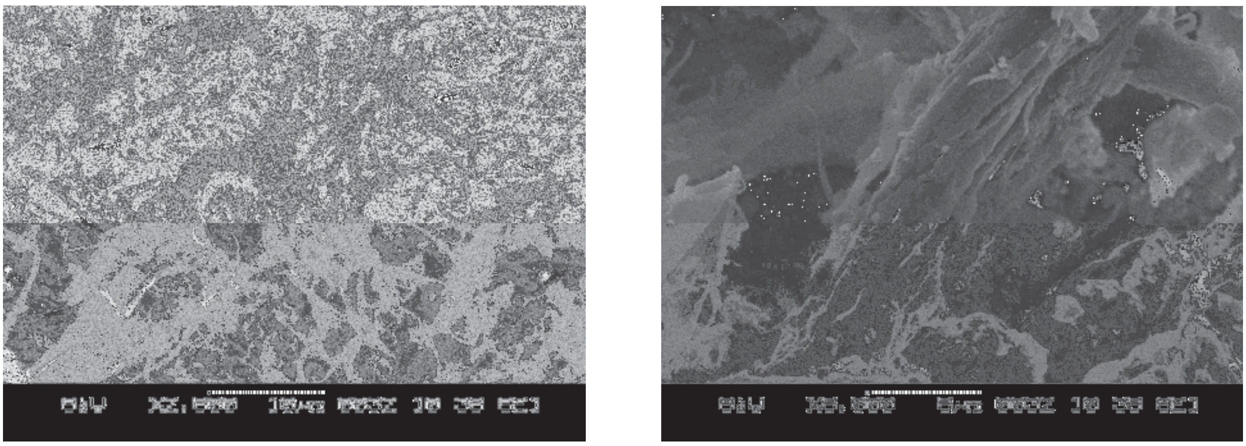

Figure 4: SEM Monograph of Virgin RPMR Sample

4.2. *BRICK ANALYSIS*

Table 5 shows the averaged test results obtained from the tests. Three brick samples of each of C0, C5, C10, C15, and C20 with dimensions of 230x105x80 mm^3 were used for the compressive strength. Another three samples each with same dimensions were tested for the specific weight, water absorption and efflorescence. All of these tests were conducted in accordance with Indian standards.

The obtained test results show that the minimum compressive strength requirements in IS 3495:1992 were obtained.

The dry compressive strength of brick samples is determined using UTM. All brick samples shows excellent compressive strength (5±0.5 MPa) as compared to conventional brick (3±0.5 MPa). Because of fibrous nature of the RPMR the brick under compressive load shrunk but did not break. The reported values are the maximum load the UTM can apply on the pulp brick sample. However with change in RPMR-FA-cement composition compressive strength does not change considerably and practically remain constant.

Because of high voidage and cellulosic nature of RPMR the water absorption is directly proportional to RPMR content. Water absorption increases by almost 40% (by mass). The percentage water absorbed can be reduced by applying water proof coating over the brick surface.

Table 5: Brick Testing Results

Sample	Compressive Strength (MPa)	Water Absorption (%)	Density (kg/m^3)	Efflorescence
Burnt Clay Bricks	3.1	14.12	1695	Nil
Fly Ash Bricks	3.12	14.64	1750	Nil
C0	4.44	65.3	1176	Nil
C5	4.78	63.4	1043	Nil
C10	5.12	60.7	885	Nil
C15	5.2	58.64	853	Nil
C20	5.6	56.23	846	Nil

6. CONCLUSIONS

The physico-mechanical properties of brick samples with paper pulp fly ash and cement as a binder are investigated. The test results show that the RPMR-FA-cement combination provides results which can be potentially used in the production of lighter and economical new brick material. The observations during the tests show high energy absorption capacity even beyond the failure load. This composition produces brick which weigh half of that of the conventional clay bricks. The observations during the tests show that bricks with the of 30% fly ash and 20% addition of cement to 50% RPMR exhibits a compressive strength of 5.6 MPa which is almost two times greater than the conventional clay bricks (3.1Mpa) and satisfies the requirements of IS 1077 for a building material to be used in the indoor structural applications. These bricks under pressure shrink but do not exhibit sudden brittle fracture even beyond the failure loads and indicate high energy absorption capacity by allowing lower manufacturing cost. The developed waste create bricks is recommended for the construction of low cost affordable housing. The present experimental study for the design and development of waste create bricks using industrial solid waste is useful to provide a potential sustainable solution.

7. ACKNOWLEDGEMENT

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USE OF RECYCLED AGGREGATES IN STRUCTURAL CONCRETE

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ABSTRACT

Properties of the recycled aggregates and the suitability of the same in structural concrete were studied and compared them with natural aggregates. The results showed that the particle size distribution of recycled aggregates is compatible with those of natural aggregates. The recycled aggregates had abrasive and impact values of 48.7% and 27.10%, respectively while those of the natural aggregates were 29.5% and 11.45, respectively. Bulk density of recycled aggregates was 1065 kg/m^3 with compared to 1296 kg/m^3 of Natural aggregates and the water absorption was 2.82% with compared to 1.22 of Natural aggregates. The mix design proposed for concrete was grade 30. Properties of concrete made under three mixing scenarios of natural aggregate to recycle aggregate proportions such as 50% -50%, 25%-75%, and 0%-100% were compared with those of 100% natural aggregates. With increasing percentage of recycled aggregate content, compressive strength, flexural strength, tensile splitting strength and workability were significantly decreased. According to the results, grade 30 concrete properties could be achieved with mix proportions of 50% natural aggregate and 50% recycled aggregate, without significantly affecting the concrete properties, indicating a 50% saving of natural aggregates thus reducing environmental impacts and enhancing sustainability.

Keywords: *Compressive Strength; Flexural Strength; Mix Design; Tensile Splitting Strength; Workability.*

1. INTRODUCTION

The invention of concrete, created an immediate and eventually permanent demand for construction aggregates. The aggregate serves as reinforcement to add strength to the overall composite material in concrete. Aggregates are among the most mined material in the world. The arrival of modern blasting methods enabled the development of quarries, which are now used throughout the world, wherever competent bedrock deposits of aggregate quality exist (Yong, 2009).

The world demand for construction aggregates was 24.9 billion metric tons in the year 2008. It is a known factor that the world today is experiencing a construction boom so the value 24.9 billion metric tons has only increased from the year 2008. The world construction aggregate demand is forecasted to expand at a rate of 2.9% annually. It is also said that if the demand increases at this rate, in the year 2013 the construction aggregate demand will reach a grand total of 28.7 billion metric tons. That is 3.8 billion metric tons of construction aggregates are used in a very short time span of five years.

According the to the Input-Output table for the year 2000 it is said that the construction industry is the largest buyer of the forest sector a total of 77.23% and mining and quarrying sector a total of 76.45%, in Sri Lanka (www.bournemouth.ac.uk/, 2012).

Almost half of the virgin aggregates in the world are used in the construction industry each year (Poon, 2012; William, 2003). The rate of construction in the world is increasing rapidly resulting in the rapid depletion of the natural resources. In Sri Lanka, demolished waste is mostly filled in land-fills.

Recycled aggregates have lighter weight per unit volume, resulting in lower bulk density. Recycled demolished concrete provides superior compaction and constructability (Parekh, 2011). The recycled coarse aggregate received by demolished concrete consist of crushed stone aggregate with old mortar adhering to it. The water absorption capacity of recycled aggregates is higher than natural aggregates

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which mean that more water needs to be added in to the concrete mix when using recycled aggregates, to get an acceptable workability (Nelson, 2004; ACPA, 1993). The abrasion values and toughness of recycled aggregates is much lower than that of natural aggregates due to the separation of the cement mortar from the recycled aggregates (Parekh, 2011). The use of recycled demolished concrete will reduce the material cost, which will reduce the haul-off cost which will reduce the overall project cost. Furthermore, costs associated with land fill disposal can be avoided. This would increase the project efficiency.

According to an investigation conducted in the year 2002, by the Ministry of Land Infrastructure and Transport (MLIT) Japan, the construction and demolition waste generated yearly is 83 million tons while 35 million tons (i.e. 42.2%) of which is concrete waste. The construction and demolition waste has reached such a high value in Japan due to many natural disasters. Recycled coarse aggregate concrete was used in the Biotope Soga symbiosis building which was installed in the Chiba Heating Power area and also in the Yokohama Thermal Power Plant premises (Yasuhiro, 2006).

Although research work conducted in some countries have indicated that recycled aggregates could be used for production of concrete, it is generally perceived by the builders in Sri Lanka, that the recycled aggregates are inferior in quality to natural aggregates. Therefore, the objective of the present study is to investigate the suitability of recycle aggregate as a construction material to produce structural concrete by testing aggregate properties as well as structural properties of concrete made out of recycle aggregates mixed with natural aggregates in three different mix scenarios.

2. MATERIALS AND METHODS

2.1. *PREPARATION OF SAMPLES*

A bulk sample of demolition building waste, crushed according to the SLS standards and collected from the COWAM centre in Galle was used as the materials for testing.

2.2. *TESTING OF AGGREGATES*

Following tests were carried out for testing the aggregates properties of recycled aggregates as well as natural aggregates.

- Sieve Analysis test - (BS-812-103.1, 1985)
- Specific Gravity and Water Absorption test -(BS 812: Part II: 1975)
- Bulk Density test - (BS 812: Part II: 1975)
- Los Angeles Abrasion Value (LAAV) test for crushing and impact value of aggregates- (ASTM C131)
- Aggregate Impact Value AIV test for impact value of aggregates - (IS: 2386 part IV)

2.3. *TESTING OF CONCRETE*

The recycled aggregates were mixed with natural aggregates under three different scenarios to evaluate the properties of concrete made using different proportions of recycled aggregates.

Table 1: Respective Percentage of Aggregates Mixed For Production of Concrete

Scenario No :	% of Recycled Aggregates	% of Natural Aggregates
1	50	50
2	75	25
3	100	0
4	0	100

The concrete cubes, beams and cylinders made were tested for 7 days, 14 days and 28 days. Three samples were made for each testing date under every scenario. The properties of concrete made according to the table 1, were compared with the concrete made with 100% natural aggregates.

The selection of the materials used to prepare the concrete and the required proportions of them was calculated according to grade 30 mix design (BRE mix design method). The workability of the each mix was tested prior to the making of concrete specimens. Curing and the testing of the specimens were done according to the BS standards.

Table 2: Initial Data Taken For The Mix Design

Target strength (MPa)	30
Water / Cement ratio	0.56
Weight of cement per bag (Kg)	50kg

Following were used for testing concrete specimens;

- Determination of compressive strength of test cubes - (BS 1881-part 116 : 1983)
- Determination of flexural strength – (BS 1881- part 118 : 1983)
- Determination of tensile splitting strength- (BS 1881- part 117 : 1983)

3. RESULTS AND DISCUSSION

3.1. *PROPERTIES OF RECYCLED AGGREGATES*

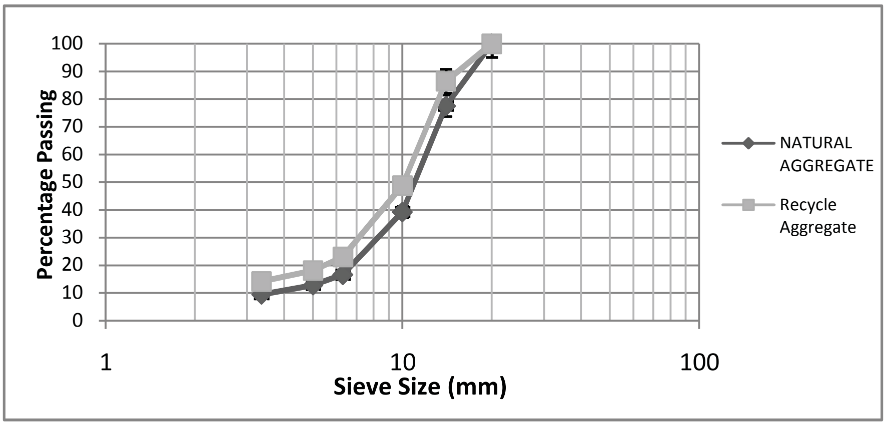

Figure 1: Gradating Curves for Natural Aggregate vs. Recycled Aggregate

Figure 1 shows the comparison of grading curves for natural and recycle aggregates. The coefficient of curvature (gradation) of recycled aggregates and natural aggregates gradation curves are 2.6255 and 2.1228, respectively showing a difference of 19.1%. The uniformity coefficient of recycled aggregates and natural aggregates gradation curves are 5.5000 and 3.5625 respectively, indicating a difference of 35.2%. Gradation affects many properties such as bulk density, physical stability, permeability etc. According to the results, it shows a dense gradation such that approximately of equal amounts of various sizes of aggregates. It is favourable for engineering applications as the bulk density is relatively high, the physical stability is satisfactory, and the permeability is relatively low, due to the well packing of particles and hence the increasing of the unit weight.

The specific gravity of an aggregate is considered to be a measure of strength or quality of the material in it. The specific gravity values obtained for recycled aggregates and natural aggregates was 1.749 and 1.571, respectively, showing a 10% reduction from natural aggregates to recycle aggregates, hence the strength is reduced. This is probably because the recycle aggregates contain some amounts of mortar attached to its surface.

The water absorption of recycled aggregates and natural aggregates are 2.815 and 1.219 respectively. The water absorption reduces around 50% from recycled aggregates to natural aggregates, probably due to the presence of abundant amount of voids in the attached mortar, concrete etc.

Aggregate density has an important influence on concrete density since aggregates occupy up to 75%-80% of the volume of concrete. So the reduction of the bulk density from NA to RA tends to decrease the relevant concrete density and this has a direct implication on the amount of self weight that the structure must carry.

The LAAV values of recycled aggregates and natural aggregates are 48.70 and 29.50 respectively. The AIV values of recycled aggregates and natural aggregates are 27.10 and 11.45 respectively. When considering the LAAV and AIV values, there was a significant reduction in abrasion and impact resistance; this is mainly due to the attached mortar being removed during the process of testing and therefore increasing the percentage of fines. Care should be taken when using recycled aggregates for pavement applications and should be verified with other properties such as surface texture, strength and elasticity, aggregate voids, hardness and particle shape as well.

3.2. PROPERTY VARIATION OF CONCRETE MADE BY USING RECYCLED AGGREGATES

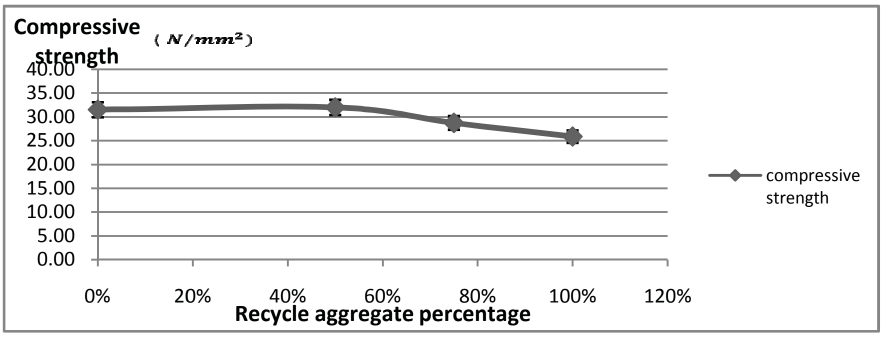

Figure 2: Compressive Strength of Concrete after 28 Days

According to Figure 2 the average compressive strength of test specimens after 28 days at the recycled aggregate content of 0%, 50%, 75%, 100% are 31.54 N/mm^2, 32.01 N/mm^2, 28.25 N/mm^2, 25.90 N/mm^2 respectively. Figure 2 shows that the concrete made with 50% recycled aggregates could achieve strength of grade 30, similar to the concrete made by using 100% natural aggregates. This indicates a 50% saving of virgin aggregate without affecting the properties of the concrete. And also the concrete made by using 100% recycled aggregates has achieved a grade 25 which is also satisfactory for various structural purposes.

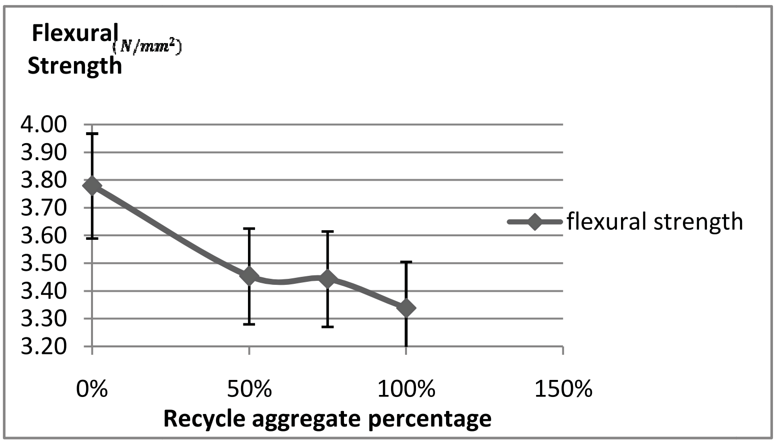

Figure 3: Flexural Strength of Concrete after 28 Days

The average tensile strength of test specimens after 28 days with respect to the recycled aggregate content of 0%, 50%, 75%, 100% are 3.78N/mm^2, 3.45 N/mm^2, 3.44 N/mm^2, 3.34 N/mm^2 respectively. According to Figure 3 there is a considerable difference in the flexural strength values of the concrete made by using 100% virgin aggregates and 50% recycled aggregates, and it should be noted that the difference is around 9%. The difference of the flexural strength values when using 100% virgin aggregates and 100% recycled aggregates is around 12%.

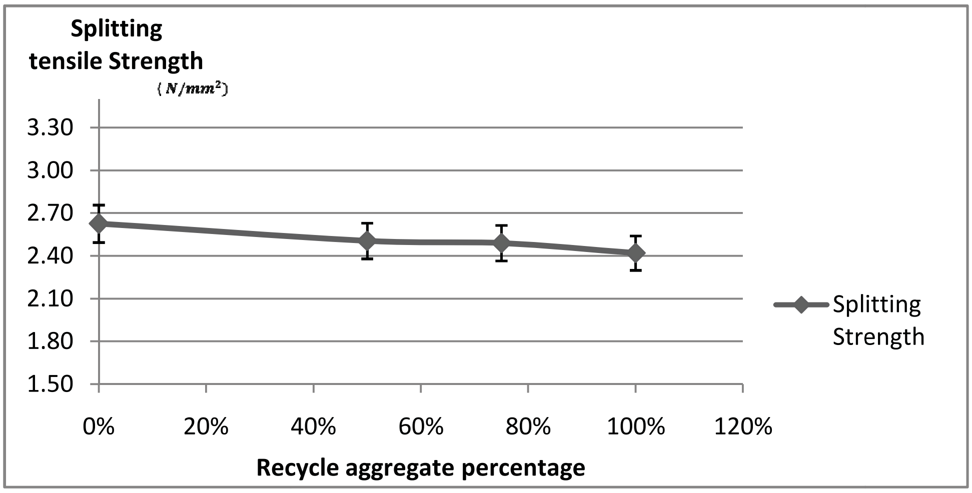

Figure 4: Tensile Splitting Strength of Concrete vs. Recycled Aggregate Content

The average splitting tensile strength of test specimens after 28 days with respect to the recycled aggregate content of 0%, 50%, 75%, 100% are 2.63 N/mm^2, 2.51N/mm^2, 2.49 N/mm^2, 2.42 N/mm^2, respectively. When observing the values which were given from the splitting tensile strength test, according to Figure 4, it can be noted that there is no significant variation in the values when increasing the percentage of recycled aggregates used. This is probably due to the better mechanical interlocking and interfacial bond due to the angular shape and rough texture of the recycled aggregates.

In general it can be noted that the use of recycled aggregates has no adverse effect on flexural strength and splitting tensile strength values.

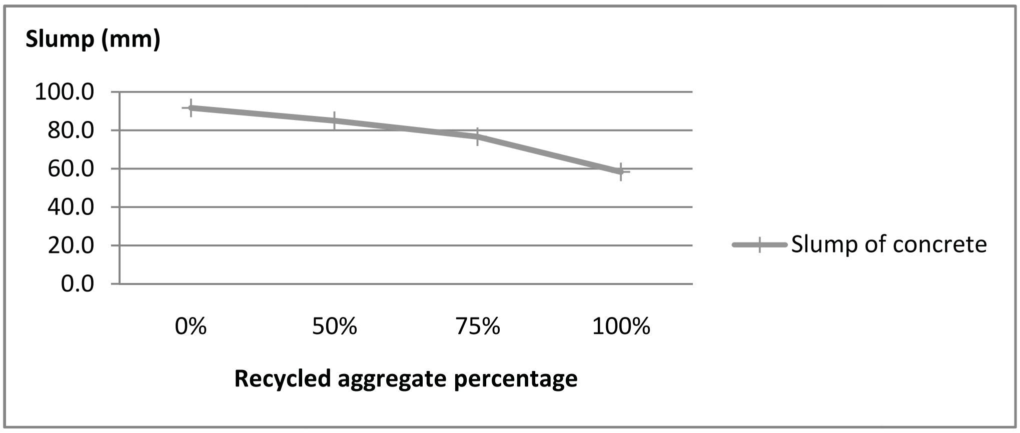

Figure 5: Workability vs. Recycled Aggregate Content

According to Figure 5, the average workability of the concrete made by using 0%, 50%, 75%, 100% recycled aggregates are 91.7 mm, 85 mm, 76.7 mm, 58.3 mm respectively. There is a reduction in the slump with the increment of recycle aggregates used in the concrete. This is mainly due to the physical characteristics of the recycled aggregate particles. The recycled aggregates used were more porous, and much rougher than natural aggregates due to the adhered cement paste. The rough-textured recycled aggregate particles increased the harshness of concrete mix, and thus decreased its workability, particularly at a greater content. The dispersion of aggregates consisting of relatively a high content of coarse particles can be lower due to increased inter-particle collisions. The loss of cement paste into the surface pores of RA also decreased the workability of concrete. Also another reason was that the amount of water added to all scenarios was kept constant and no add mixtures were used. The pore spaces in the attached mortar on the recycled aggregates would have absorbed a fair quantity of water, hence reducing the workability of the concrete (Kosmatka and Panarese, 1994).

4. CONCLUSIONS

Although some negative results were shown when testing the aggregate properties of recycled aggregates, there were no significant adverse impacts in the concrete being made from recycled aggregates. Due to the light weight of concrete and lower bulk density, it can be used with thin sections in high rise building. Though the workability reduced with RA, it should be noted that there are many admixtures in the market to overcome the issue.

Finally, it can be conclude that at least 50% of natural aggregates can be easily replaced with recycled aggregates in concrete, without significantly affecting the concrete properties, indicating a 50% saving of natural aggregates thus reducing environmental impacts and enhancing sustainability.

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USE OF SUSTAINABLE MATERIALS IN CONSTRUCTION INDUSTRY CONTRACTOR'S PERSPECTIVE

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ABSTRACT

Buildings are the largest energy consumers and greenhouse gas emitters, both in the developed and developing countries. Therefore, it is a dire need in the present status quo to shift to sustainable buildings. Sustainable buildings can be identified as a spectrum of buildings, designed and constructed using methods and materials that are resource efficient and that will not compromise the health of the environment, wellbeing of the building occupants, construction workers, general public or up and coming future generations. In the process of construction of sustainable buildings, while striking a balance between the triple bottom line, environmental, social and economic sustainability, construction material is given a higher priority. Therefore, this research reflexes the use of sustainable building materials in the construction industry.

In the research process, initially a comprehensive literature synthesis was carried out to get an insight on the concept of sustainability and sustainability construction. This was then followed by a questionnaire survey among the M1 and M2 contractors of Sri Lanka. Through the study it was evident that there is perfect knowledge available on the concept of sustainability even though only 48% of the contractors have used sustainable materials in construction. It is necessary to comment that sustainability has now become mandatory in order to tackle many environmental problems. Thus, the usage of sustainable materials in construction is at the verge of being a mandatory requirement in construction. Therefore, this research provides a firm basis to use sustainable materials in construction industry in the perspective of construction contractors.

Keywords: *Construction Industry, Contractor, Sustainability; Sustainable Material.*

1. INTRODUCTION

Global warming and many other environmental issues are considered the most stressing issues that are currently being faced by humanity. There are controversial arguments being made among professionals of different spheres in order to develop strategies to face these issues which put the entire human race in to lurch. One of the major solutions for these issues is to introduce a major change in the current lifestyle in order to preserve the planet (Toufic, 2011). However, with the rapid changes to lifestyle of people meeting the two ends of catering the human needs while preserving the planet has become an impassable gulf. Hence in the present status quo, in order to balance these two extremes the concept of "Sustainability" has come in to light and it considered to be the buzz word of the decade.

Earlier in 1987, Bruntland, illustrated on sustainability as meeting the needs of today without compromising the ability of future generations to meet their own needs. According to Singhaputtangkul *et al*. (2005), the core of mainstream sustainability thinking, is to strike a balance between three dimensions namely, environmental, social and economic sustainability. Simplistically it can be argued that sustainability will be achieved when all consumers can make choices to conserve, to minimize damage and to maximize benefits. The term sustainability has been adopted as a panacea for change and development (Hayles, 2004). Hence, in a nutshell it can be depicted that sustainable

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buildings have a minimal negative impact on the built and natural environment. Further, these buildings should meet a number of certain objectives: resource and energy efficiency, CO_2 and Green House Gas (GHG) emissions reduction, pollution prevention, mitigation of noise, improved indoor air quality and harmony with the environment (John *et al*., 2005).

As far as a building is concerned, the material used in construction has a greater impact on the sustainability. This is due to the fact that all materials are ultimately derived from the bio-Geo-sphere. The choice of materials for construction controls whole life cycle impacts such as environmentally unhealthy emissions, increase in non degradable wastes and many other adverse impacts. Moreover, materials strongly influence on lifetime energies, user comfort and durability (Harrison, 2006). Hence it is a need of the society to further study on the inputs of materials in sustainable construction.

2. LITERATURE REVIEW

2.1 SUSTAINABLE CONSTRUCTION

The need to enforce sustainable construction is important as what is built today will provide the built environment of the future and will influence the ability of future generations to meet the needs (Dickie and Howard, 2000). Sustainable construction, a subset of sustainable development, advocates the use of technology and knowledge to improve the sustainability of designing, constructing, and operating infrastructures (Chong *et al*., 2009). According to Ospina *et al*. (2010), sustainable construction is the process of planning, designing, constructing, maintaining, and operating building projects, with the goal of minimizing overall environmental impacts and maximizing the benefits to the final users and to the surrounding community. As per Ospina *et al*. (2010) in order to develop a sustainable project, it is necessary to rethink design, construction and operational aspects of energy, water and resource use, indoor air quality, recycling programs, alternative transportation access, landscaping strategies, construction waste management, construction site planning and management, wastewater management and maintenance among others. Hence it is necessary to derive the fact that sustainable construction is not merely a product, it is a process in the very outset. Moreover, from the very beginning, which is from the design stage onwards "sustainable construction" approaches must be adopted and practiced. According to Tres (2000), in order to reach a sustainable design, it is necessary to design for material substitution with higher environmental impact to most superior materials in terms of sustainability.

2.2 BUILDING MATERIALS USED IN CONSTRUCTION

As explained by Venkatarama-Reddy and Jagadish (2003), building materials, technologies, and building practices have evolved through the ages. Housing and building conditions reflect the living standards of a society. As an example, it is necessary to state that stones, mud, thatch/leaves and timber represent the earliest building materials used for the construction of dwellings. Therefore, hardly any energy is consumed in manufacturing and using of these natural materials for construction in the early days. However, in present these have been drastically changed due to the enhancements of the living standards of the people.

The discovery of natural inorganic binders like pozzolanic materials leads to the use of lime-pozzolana (LP) cement for construction purposes. Experience of using LP cement, paved the way for the invention of Portland cement in 1824 (Venkatarama-Reddy and Jagadish, 2003). Portland cement and steel brought revolutionary changes in the construction practices from the early part of the 20th century. Then plastics and plastic products entered the construction industry. Bricks, cement, steel, aluminium, plastic products, paints, polished stone and ceramic products are the commonly used materials of construction today. However, these materials are energy intensive and the necessity to transport over large distance before being used further add up more energy utilisation (Venkatarama-Reddy and Jagadish, 2003).Hence, with the evolution through the years on construction and building practices have introduced greater problems at present.

Therefore, it is necessary to note that it is a dire need to address these aspects of sustainable materials utilization in the construction industry. To address the goals of sustainable development the production of materials must use resources and energy from renewable sources instead of non-renewable ones. However, Sustainable Building Materials (SBM) should pose no or very minimal environmental and human health risks (Calkins, 2009). According to Joseph and Tretsiakova, (2010), these should also satisfy the following criteria: rational use of natural resources; energy efficiency; elimination or reduction of generating waste; low toxicity; water conservation; affordability. On the other hand, SBM can offer a set of specific benefits to the owner of a building such as reduced maintenance and replacement costs, energy conservation, improved occupant's health and productivity, lower costs associated with changing space configurations, and greater flexibility in design (Joseph and Tretsiakova, 2010).

According to Abeysundara *et al.* (2009) the major environmental burden evolved in Building Materials (BM) relate to the embodied energy of BM and Green House Gass (GHG) emissions originated from each stage of the life cycle. Embodied energy is defined as the amount of energy required to produce a material and supply it to the point of use. It is an important measure of the effectiveness of BM in the environmental terms (Abeysundara *et al*., 2009). Embodied energy consists of: energy required for the manufacturing of BM; energy associated with the transportation of raw materials to the factory and of the finished products to the consumer; the energy needed for assembling various BM to form a building (Venkatarama- Reddy and Jagadish, 2003). The results presented by Thormark (2006) indicated that the embodied energy in traditional building can be reduced by approximately 10–15% through proper selection of Sustainable Building Material (SBM) with low environmental impacts. Although the values of embodied energy can vary widely, these can be considered as reasonable indicators of an overall environmental impact of BM (Joseph and Tretsiakova, 2010). Hence in order to promote sustainable construction it is necessary to select the most suited SBM based on those aspects.

2.3 SELECTION OF SUSTAINABLE BUILDING MATERIAL

In order for the decision makers to select materials suitable for sustainable construction, the assessment of the relevant environmental burdens is necessary (Joseph and Tretsiakova, 2010). Further, the appropriate materials for sustainable sites will vary by impact priorities, regional issues, project budgets and performance requirements. In addition to varying priorities and goals in the green material selection, there are shades of green. For instance, the ideal green material might be a natural, renewable, local and indigenous, nontoxic, low embodied energy material such as willow cuttings for slope stabilization or rammed earth for a retaining wall (Calkins, 2009). However, there may be certain materials which does not totally contribute as a SBM, but may be considered as a shade of green whereas partly contributing to sustainability.

According to Onyegiri *et al* (2011), each building material has its own advantages and disadvantages. Some of the problems with existing materials are their poor use of environmental resources, poor quality control of the finished product and consequently a significant variation in durability. Hence, based on those facts it is necessary to identify that in order to select SBM, the features related to these materials must be given a consideration. Hence, as stated by Kim (1998) these selection criteria can be surmised as follows which are identified as some of the features of SBM

- Pollution Prevention Measures in Manufacturing
- Waste Reduction Measures in Manufacturing
- Recycled Content
- Embodied Energy Reduction
- Use of Natural Materials
- Reduction of Construction Waste
- Local Materials
- Energy Efficiency

- Water Treatment and Conservation
- Use of Nontoxic or Less-Toxic Materials
- Renewable Energy Systems
- Longer Life
- Reusability
- Recyclability
- Biodegradability

In addition, one of the most important features of a sustainable building is the material efficiency. Correct selection of BM can be performed by taking into account their complete lifetime (from cradle to grave) and by choosing products with the minimal environmental impacts (Joseph and Tretsiakova, 2010). The use of renewable and recycled sources is widely encouraged as the life cycle of a building and its elements can be closely related (Chwieduk, 2003). The other factors that greatly affect the selection of BM are the costs and social requirements such as thermal comfort, good mechanical properties (strength and durability), aesthetic characteristics and the ability to construct quickly. Ideally, the combination of all environmental, economic and social factors can give a clear description of a material and thus, helps in a decision making process regarding the selection of the materials suitable for buildings (Abeysundara *et al*., 2009).

Taking all these aspects into a nutshell Subramanian (2007) identified the following rules which can be used. As per Subramanian (2007) selected materials:

- should consume less energy to manufacture
- should not involve long distance transportation (for the raw materials as well as a finished product)
- should not affect the environment
- should be easy to recycle and safe to dispose into landfills
- should be harmless in production and use
- dissipated during recycling must be harmless
- should have long life and durability
- should be easy to disassemble.

Indeed, sustainable buildings generally incur a green premium above the costs of standard construction, and however these also provide an array of financial and environmental benefits that conventional buildings do not (Kats, 2003). These benefits, such as energy savings, should be looked at through a life cycle cost methodology, not just evaluated in terms of upfront or initial costs. Hence it is necessary to that selection of materials for construction is the most effective way in which sustainability can be promoted.

3. RESEARCH METHODOLOGY

The research problem statement of this study was developed as; “Use of sustainable materials in the construction industry: contractor’ perspective”. Therefore in order to collect the opinions and issues from contractors and their perception about the usability of sustainable building construction materials in local industry, a quantitative research approach has been used in this research study. Hence a questionnaire survey was carried out in order to rank the priorities of contractor’s perception.Initially, the questionnaire focused on contractor’s approach on material selection in building constructions. This was then followed by a series of questions attempting to identify the contractor’s opinion of using sustainable materials. Finally, the questionnaire survey focused to identify and reveal the key issues and barriers faced by the contractors while handling sustainable building materials.

In the questionnaire which was distributed among Grade M1 contractors requested to respondents to indicate the relative importance ratings for the listed building materials, factors, characteristics and problems regarding sustainable building constructions. A five-point Likert scale (i.e.5 = very high contribution and 1 = very low contribution) and a three point Likert scale (i.e.3 = very high contribution and 1 = very low contribution) were used.

The data analysis was done by using the Relative Important Index (RII) formula. Many researches (El-Sayegh, 2008; Jeyamathan and Rameezdeen 2006) have identified RII as a data analysis technique in order to rank the factors and identify the most significant factors. 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 as cited in Gunawardana *et al.,* 2004).

$$RII = \frac{\Sigma (W\,n)}{A \times N} \times 100\,\%$$

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.

Thus, the relative index shall change from 0% to 100%.For this research thirty (30) questionnaires were distributed among thirty Grade M1 contractors, who are involved with building construction projects, and only 25 questionnaires were answered leading to a response rate of 83.33 percent.

4. DATA ANALYSIS AND FINDINGS

4.1. CONTRACTOR'S AWARENESS ON THE CONCEPT OF SUSTAINABILITY

Through the questionnaire survey the contractors were questioned on the awareness on concept of sustainability. It is interesting to note that all the respondents were aware of the concept very well. This simply shows that sustainable concept is not a "total alien" concept to the industry and especially among the contactors. However, although it is familiar within the industry it is required to further investigate to which extent this concept is put in to practice in the present status quo.

Hence as a result, most of the contractors were into an in depth study of this concept. According to certain individual opinion, still it was not successful and popular in Sri Lankan industry. Moreover, it was revealed that as an active stakeholder in the construction industry, the respondents expect to work with modern technologies and change the existing traditional situation as soon as practicable.

4.2 SUSTAINABLE CONSTRUCTION IN PRACTICE: SELECTION OF MATERIAL

Although there were 100% of awareness among the contractors on sustainable construction practices within the industry, out of them 36% were involved in practicing sustainable materials for building construction work.

This figure of 36% could provide a better picture of the prevailing situation of the industry and its actual perception towards sustainable construction. Further, 64% of the respondents identified sustainable construction as impracticable in the general scenario. However, in certain cases respondents agreed with some aspects of sustainability and further it was mentioned that although the concept is not directly put into practice certain aspects were put in to practice within the industry.

4.3. UTILIZATION OF SBM IN PRACTICE

In practice, based on the derived results, only 48% of the respondents stated that SBM are consciously used in the construction. Sri Lanka being one of the developing countries, according to the contractor's perception it was mentioned that enough enforcement is not stipulated for the effective utilization of sustainable materials.

With this set of findings it is necessary to derive that, there is a serious conflict between the awareness of the sustainability concept and the practical adoption of it within the construction. However, further in the questionnaire the respondents were asked to rank the materials as per the usage in the construction industry and further to rank the sustainable materials aspect. Since the awareness of the sustainability concept is higher most of the contactors identified materials such as Clay tiles, Straw, Plywood and Metal as the top five sustainable materials used in construction. Materials ranked as per the sustainability as well as the current usage in the industry are given in Table 1.

Table 1: Sustainable Materials

Material	**RII As per the sustainability**	**Rank as per the sustainability**	**RII As per the usage**	**Rank as per the usage**
Clay tiles	0.608	1	0.232	13
Straw	0.528	2	0.200	15
Ply wood	0.488	3	0.272	11
Metal	0.472	4	0.472	4
Bricks	0.448	5	0.448	6
Sand	0.392	6	0.736	2
Timber	0.368	7	0.360	9
Carpet	0.336	8	0.200	15
Glass	0.288	9	0.432	7
Rubble	0.264	10	0.296	10
Cement	0.256	11	0.816	1
Blocks	0.248	12	0.472	4
Aggregates	0.240	13	0.384	8
Reinforcement	0.240	13	0.592	3
Asbestos	0.240	13	0.256	12
Plastics	0.200	16	0.200	15

Through Table 1, it is possible to depict a clear picture on the contribution of certain materials towards the sustainability concept. As per Table 1, if materials such as Clay tiles, Plywood and straw were considered, these were identified as the material with the least usage. However, those materials were also identified as the materials which mostly contribute to the sustainability in construction. Further, contradictorily, materials such as cement, blocks, aggregates and reinforcement are heavily used in construction industry although it is identified as the least sustainable materials. Hence, in either way it is necessary to draw the attention that, in most of the circumstances, mostly used materials in construction does not contribute to sustainability in construction. As a result, a higher consideration must be given to selection of sustainable materials in building construction in order to deploy more sustainable material. For that purpose, it is necessary to identify the factors which affect the selection of SBM in construction.

4.4. Factors Affecting the Selection of SBM

As per Section 4.2 it was identified that irrespective of the awareness of sustainability in construction only a very few, which amounting to 37% identified this as a practical solution. Hence it is worth to exploring the reasons behind this conclusion or else identifying the obstacles in selecting SBM in construction. Based on the feedback of the respondents certain factors were identified as the governing factors which directly affect the selection of SBM. Further, these factors were graphically illustrated in Figure 2.

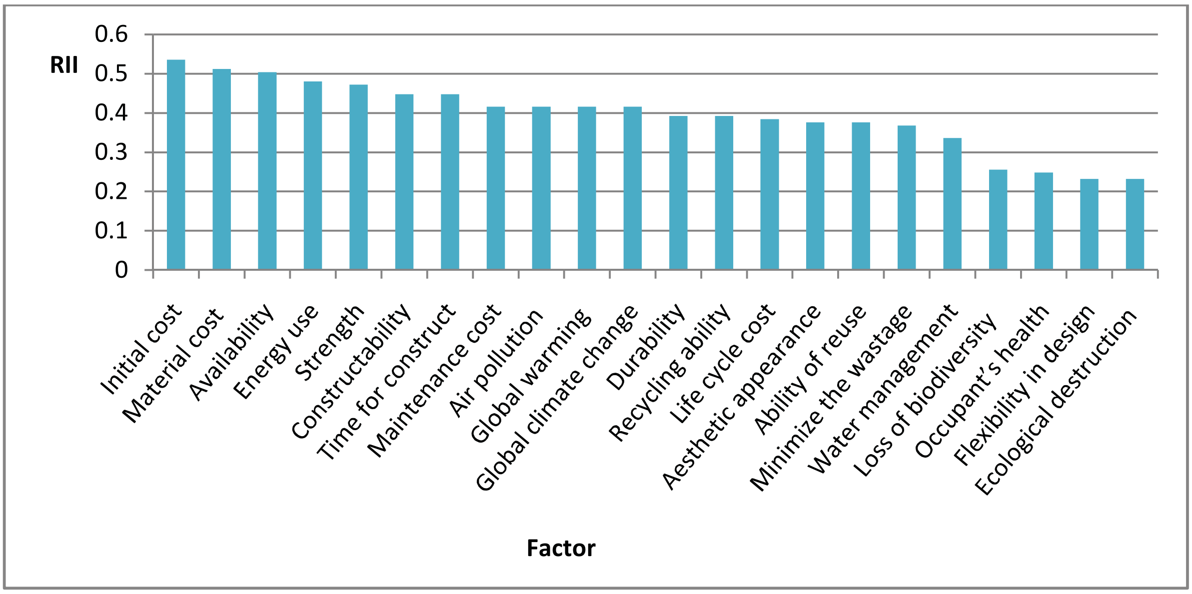

Figure 2: Factors Affecting the Selection of SBM in Construction

Figure 2, illustrated that Initial cost and the material cost have played a major impact on selection on SBM. Further, it was revealed that if the costs relating to SBM are high, that would be the governing reason of lack of usage of SBM in construction. However, factors which depict the essence of sustainability such as Air pollution and Global warming is at the medium range of factors which affect the selection of SBM. Further certain factors such as water management and bio-diversity has a very lower impact in the process of SBM. Hence it is necessary to argue that contractors use SBM within the industry not merely for the sake of sustainability in construction and however, there is a subtle intention of sustainability is available. Moreover, it is necessary to note that there is no major factors affecting the selection and only slight variations of importance in affecting the selection is available.

Further in literature there were certain features were identified many researches (Subramaniam, 2007; Kim, 1998) as feature which should be embodied in SBM. However, as per these results of Figure 1, it is necessary to conclude that due to the cost impact shades of green may be more practicable and accepted within the industry (See Section 4.2).

4.5. Problems Encountered when Using SBM

In the construction industry, the usage of sustainable concept in practice is considerably low (See Section 4.2). However, there may be issues which govern this drawback. Hence the respondents were asked to identify the problems encountered while using SBM and rank them as per the criticality as shown in Table 3.

Table 3: Problems Encountered when using SBM

Problems	RII	Rank
Prices of materials	0.536	1
Initial cost	0.512	2
Suitability for modern world	0.488	3
Effects to the environment	0.480	4
Available alternatives	0.400	5
Strength	0.376	6
Durability	0.376	6
Aesthetic appearance	0.352	8
Prices of alternatives	0.312	9
Thermal comfort	0.280	10
Ability to construct quickly	0.272	11
Necessity of skilled person	0.272	11
Sub contractor's knowledge	0.264	13
Appropriate technology	0.264	13
Appropriate machinery	0.256	15
Weather changes	0.256	15

In conjunction with the results depicted in Table 2, it is inevitable to conclude that higher prices of materials and the higher initial cost are the governing factors which prevent the usage of SBM in physical construction. Further, Table 2 clearly shows that cost or the financial consideration was given a higher impact in selecting SBM. Further this fact was proven that due to the higher cost of SBM were rarely practiced in the construction industry. The availability of the skilled personnel, lack of appropriate technology and machinery were given the least ranking. This clearly illustrates the fact that the industry is at the moment in possession of requires awareness and knowledge. However, certain other factors are refraining the usage and adoption of SBM into the practice.

5. CONCLUSIONS

Nowadays, principles of sustainability have become mandatory in order to tackle global warming and the associated climate change. Governments of several countries have adequate policies in place with a view to control and improve the current state of the construction industry. The major actions include minimization of energy consumption in the buildings, rational use of natural resources and strict control of the emissions. All these measures should systematically apply during the selection of materials which suitable for sustainable buildings and construction activities.

In the arena of sustainability, the contractors' approach on material selection plays a major role. This research attempted to discuss the contractors' opinion on use of sustainable materials, key issues and barriers faced by the contractors. The results of the survey were evident that in the construction industry, the awareness of the concept of sustainability is at its acme. However, the practical usage of this concept is quite questionable. According to the results derived by the survey, irrespective of the awareness, 64% argued on the fact that practicality of sustainable of construction is questionable butsome believes that certain aspects of this can be put into practice.

In the perspective of utilization of SBM, Clay tiles were identified as one of the highly preferred sustainable building material utilized by contractors. In the selection of these materials, financial aspects were given the highest priority. However, it was found that the cost of the material and the initial cost are mostly considered while selecting materials. Moreover, it was necessary to illustrate that both these costs were considerably high in SBM. In addition, it was identified that the required knowledge and skills were at the required level for the construction to be sustainable. However, usage of SBM is lagging behind mainly due to the financial issues stated by contractors.

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UTILITY FACTORS AFFECTING FOR SELECTING DELAY ANALYSIS TECHNIQUE

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ABSTRACT

Delays in the completion of scheduled activities as per the work plan will invariably lead to delays in construction. Such delays play havoc in the construction industry especially in a sustainable environment leading to many issues and disputes which in many cases retard the progress of the project. Therefore, minimizing delays is one of the most important factors in sustainable construction. Due to its criticality, a wide range of Delay Analysis Techniques (DAT) has been developed by various analysts over the years to address the issue. Further, with the emergence of new scenarios in sustainable construction with the passage of time, analysts have identified the inherent properties of each of these methodologies. These inherent properties or factors in turn become indicators for measuring the suitability and accuracy of DAT in a given context where they can be grouped into filter and utility factors. However, in the Sri Lankan construction industry, the resolving and managing of construction delays remain at an elementary stage with most analysts opting for an ad-hoc selection rather than being governed by considerations of suitability. This paper contains the findings of a literature review and interviews with experts which compare DAT and factors affecting the selection of DAT. The methodology adopted in undertaking this research is a case study and document reviews. The findings of the study will direct analysts to select the most suitable DAT and to reduce the error margin in delay analysis while aiding the increase in accuracy of delay analysis.

Keywords: *Construction Delays, Delay Analysis Techniques (DAT), Utility Factors*

1. INTRODUCTION

Delay is one of most common claim types occurred in construction industry. Sometimes these claims may place havoc and be more complex and be difficult to resolve. Hence it is necessary to focus on the delay analysis methods adopted in resolving claims as the result of the delay analysis may be influenced by the method or technique selected. Therefore selecting most appropriate technique is more important to concern all parties. For that analyst has to consider factors affecting for selecting Delay Analysis Technique (DAT). However, despite of its importance, in Sri Lankan construction industry there is no proper way to select appropriate delay analysis technique for particular scenario. The work is a part of an on-going research with a broader aim of building up a framework for selecting most suitable delay analysis technique by using utility factors into Sri Lankan building construction industry.

2. AIM AND RESEARCH METHODOLOGY

The aim of this paper is to provide a conceptual frame work for selecting suitable DAT for particular scenario by considering utility factors. The methodology adopted in undertaking this research is a comprehensive literature review and a series of interviews with experts from the construction industry. The findings from the literature review were modified according to the Sri Lankan context with the use of interviews. The interviews were carried out with four experts, who have more than 20 years' experience in the construction industry.

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3. CONSTRUCTION DELAYS

Construction delays can be defined as "the late completion of work compared to the planned schedule or contract schedule" (Wei, 2010, p.05). Delay is often used to refer the time period during which some part of the construction project has been extended beyond what was originally planned due to unanticipated circumstance (Bramble and Callahan, 2000). Further, they mentioned that the time that is allowed to perform particular construction is usually an important consideration for both the client and the main contractor. However, it is typical for construction projects to be delayed due to several reasons (Kraiem and Diekmann, 1987). Delays in construction can cause a number of changes in a project such as late completion, lost productivity, acceleration, increased costs, and contract termination (Semple *et al*., 1994). When construction delays occur, it is necessary to ascertain the liabilities of the contracting parties and to direct the appropriate amount of resources to recover the schedule (Lyons and Skitmore, 2004).These construction delays can be categorized into different types according to the responsibility of the party.

4. CONSTRUCTION DELAY TYPES

Number of authors (Kraiem and Diekmann, 1987; Menesi, 2007; Keane and Caletka, 2008; Enshassi *et al*., 2009) has proposed various delay types which occurred in construction environment. Further, certain authors used different names to introduce or address same delay type such as Kraiem and Diekmann, 1987 and Keane and Caletka, 2008. Keane and Caletka, 2008 used the name Non-excusable delays whereas Enshassi *et al*., 2009 and Menesi, 2007 used it as Inexcusable delays. According classification introduced by those authors and the results of the interviews the following summary was derived.

Table 1: Delay types by Literature and Availability of Delay Types in Sri Lanka

Author(s) / Delay Type		Kraiem and Diekmann, 1987	Keane and Caletka, 2008	Enshassi *et al*., 2009	Menesi, 2007	Availability in Sri Lanka according to interviews
D_4	Excusable	√	√	√	√	4
D_3	Inexcusable			√	√	3
	Non-excusable	√	√			
D_1	Compensatory	√				1
	Compensable		√		√	
D_2	Non-compensable		√		√	2
D_5	Concurrent			√	√	5

However, considering most of the classifications made by different authors and experts in the Sri Lankan construction Industry, following delay types can be identified as most common delay types.

- Non-Compensable Delays - Delays for which the contractor is entitled to a time extension and however, contractor is not entitled to any additional monetary compensation.
- Compensable/ Compensatory Delays - Delays that are unforeseeable and beyond the contractor's control, but for which the contractor is entitled to not only a time extension but also additional compensation.
- Non-Excusable/ Inexcusable Delays - Delays that are foreseeable or within the contractor's control.

- Excusable Delays - Delays that are unforeseeable and beyond the control of the contractor.
- Concurrent delays – Delays which are two or more delay events occurring within the same time period, each independently affecting the Completion Date.
- Concurrent delays – Delays which are two or more delay events occurring within the same time period, each independently affecting the Completion Date.

In almost all instances though it is relatively a simple project, the analysis of delays in construction project is difficult and complicated because of the large number of individual activities that have to be dealt with (Shi *et al*., 2001). In order to manage that complexity of processing construction delays, number of techniques introduced in many literature sources, journals, articles and books (Yang *et al*., 2006).

5. DELAY ANALYSIS TECHNIQUES (DATS)

Construction Law delay and disruption protocol (2002) illustrated that there are five commonly used Delay Analysis Techniques (DATs), which are namely Impacted as-planned method, Time impact analysis method, Collapsed as-built or 'but-for' analysis method, Snapshot/ windows/ time slice analysis method and As-planned versus as-built method. Further, Yang *et al*. (2006) also identified As planned versus as built technique, Impacted as planned technique, But-for technique, Time impact technique and these are some special and famous techniques use in construction industry to analyse construction delays.

Other than the above DAT, various delay analysis techniques have been proposed in many literature sources and alternative names used by different authors for same method (Hegazy and Zhang, 2005). Sometimes different researchers used different names (Highlighted techniques in Table 2) to express same technique. For an example Yang *et al*. (2006) used the name "Windows technique" to express DAT whereas Alkass *et al*. (1995) used it as "Snapshot technique". Following table (Table 2) refers various delay analysis method proposed by different authors. In addition based on the interviews results, in the last column of table 2, it shows that the level of usage of methods in Sri Lankan construction industry.

The interviews conducted with the experts in Sri Lankan construction industry, shows that following techniques can be identified as techniques which are currently use in Sri Lankan building construction industry. Not only that but also these are the delay analysis techniques which most authors identified as most famous and special DAT (Refer table2).

- Global impact technique
- As planned vs as built
- Impacted as planned
- Time impact technique
- Collapsed As-built

Each and every DAT has own inherit qualities and therefore selecting the most appropriate DAT leads to a fair and effective evaluation which impact on delay and also with the available information it will provide a reliable solution within the time and cost allocated for this purpose (Arditi and Pattanakitchamroon, 2006). Bubshait and Cunningham (1998) argued that all situations cannot be fulfilled by one particular DAT and it is necessary to identify the most appropriate technique for each scenario. Braimah and Ndekugri (2008) mentioned that the result of the delay analysis is influenced by the method or technique selected. Further they have discussed that while identifying the most appropriate technique for particular scenario will give fair result for both parties.

Table 2: Various DATs in literature and Use of DATs in Sri Lanka

Delay Analysis Technique / Author(s)	Yang *et al.*, 2006	Yang and Kao, 2007	Lee, 1983	Kraiem and Diekmann, 1987	Reams, 1989	Wickwire *et al.*, 1991	Alkass *et al.*, 1995	Leary and Bramble, 1998	Chehayeb *et al.*, 1995	Rubin *et al.*, 1999	Pinnell, 1998	Lucas, 2002	Stumpf, 2000	Lovejoy, 2004	Wickwire and Groff, 2004	Interviews Result (Whether use in Sri Lankan industry or not)
Global impact technique	√	√	√	√	√	√	√	√	√		√					Using
Net impact technique	√			√					√							Not used
Adjusted as-built CPM technique	√	√					√	√								
As planned vs as built			√	√		√			√			√	√	√		Using
Total time															√	
Impacted as-built CPM					√						√					
As planned but for							√				√					Not used
Impacted as planned		√	√	√	√	√			√	√	√	√			√	Not used
Collapsed As-built	√	√	√	√	√	√	√	√			√			√	√	Using
As-planned expanded technique	√	√														Not used
Collapsed but-for technique	√						√	√	√							Not used
Snapshot technique			√	√	√	√	√	√	√							Using
Windows technique	√	√												√		
Time impact technique	√	√	√	√	√	√	√	√	√							Using
Isolated delay type technique	√							√								Not used
Apportionment delay					√		√		√							Not used
S- Curve										√						Not used

6. FACTORS AFFECTING THE SELECTION OF DELAY ANALYSIS TECHNIQUE

6.1. IDENTIFICATION OF FACTORS

Selection of the most appropriate technique is more important to concern by all parties (Braimah and Ndekugri, 2008). Society of Construction Law's protocol (SCL) (2002) has identified number of requisites that analysts should focus in order to identify the most suitable DAT for the respective scenario. Ramanathan *et al*. (2012) illustrated that selection of DAT depends on time of analysis and capabilities of the method, the relevant conditions of contract, the nature of the causative events, the value of the dispute, the programme information available and the programmer's skill level and familiarity with the project characteristics and characteristics of baseline programme can be considered as some main group factors followed by several sub factors for the selecting of an appropriate DAT. Similarly Arditi and Pattanakitchamroon (2006) and, Braimah and Ndekugri (2008) also introduced well developed six number of group factors which included eighteen sub factors that influence the selection of DAT for United Kingdom construction industry.

However, it is necessary to elaborate that in the perspective of Sri Lankan construction industry professionals, they may have different perspectives and attitudes compared to United Kingdom construction industry professionals. Therefore based on all of the above findings, twenty numbers of factors can sum up as follows which are influenced to implement an accurate delay assessing method in Sri Lankan construction industry (Refer table 3). These factors were identified through an interviews carried out among four professionals in the Sri Lankan industry. Further, in order to get a better insight to this research previously identified factors through the literature were brought to the attention of the industry professionals and the most suited factors in the Sri Lankan context were identified.

6.2 CATEGORIZATION OF FACTORS

All factors including sub factors affecting for selection of suitable DAT can be divided into "Filter factors and Utility factors" (Gunarathne, 2012). Further he illustrated that utility factors represent the required level of utility of the factors to be considered by parties, when selecting a single DAT against the inheriting properties. Furthermore Gunarathne (2012) has mentioned that to select most appropriate DAT, primary screen out can be done by using filter factors and after filtering out certain techniques from filter factors, selecting appropriate method depends on weighting of DATs and utility factors. Therefore considering utility factors for selecting DAT is a more advanced method than selecting from filter factors. Simultaneously, the systematic and accurate consideration of the utility factors will increase the accuracy level of delay analysis while decreasing the potential error margin.

Among the factors which have mentioned above some have conceives as utility factors by the selected four experts who were involved in the survey. The other remaining factors are considered as filter factors which consists 0.5 probability to each of "yes" and "no" responses by the relevant context properties. According to the delay analyst's approach the utility factors would vary along the utility of the analyst whereas the filters would remain unchanged. As a conclusion identified factors and the categorization can be presented as below.

Table 3: Factors Affecting for Selecting DAT

Factors Identified		Utility factor	Filter factor
U_1	Record availability	√	
U_2	Nature of baseline programme	√	
U_3	The other party to the claim	√	
U_4	Applicable legislation	√	

	Factors Identified	Utility factor	Filter factor
U_5	The form of contract	√	
U_6	Skills of the analyst and familiarity with the project	√	
U_7	Size of the project	√	
U_8	Duration of the project	√	
U_9	Complexity of the project	√	
U_{10}	The amount in dispute	√	
U_{11}	Dispute resolution forum	√	
U_{12}	Time availability for delay analysis	√	
U_{13}	Cost of using the technique	√	
F_1	Nature of the delaying events		√
F_2	Baseline programme availability		√
F_3	The number if delaying events		√
F_4	Updated programme availability		√
F_5	Time of the delay		√
F_6	Reason for the delay analysis		√
F_7	Nature of the proof required		√

6.3 IMPACT OF THE UTILITY FACTORS TO INCREASE THE ACCURACY LEVEL OF DELAY ANALYSIS

Record availability - Under record availability, it concern about the project's factual records required for delay analysis. Those can be identified as contract documents, letters, minutes of meetings, notes, material receipts, supervision and inspection reports, resource data and costs, daily reports, extra work orders and progress reports. (Gunarathne, 2012)

Nature of baseline programme - This consider about the format of the baseline programme such as bar chart or critical path method and its quality or the accuracy level to carry out an accurate delay analysis (Braimah and Ndekugri, 2008).

Applicable legislation - Applicable legislation means the contract clauses relating to programming and progress control requirement may have a bearing on the availability of contract programmes and its updates, which in turn facilitate the use of certain delay analysis technique to a greater extent than others.

The form of contract - Form of contract itself provides the requirements which would affect the analysis directly.

Cost of using the technique - Analysing delay claims can be costly and time-consuming process particularly when using methods such as time impact analysis and window analysis. This makes it necessary to consider the value of the claims in dispute in relation to the cost involved in resolving it to ensure the selection of a cost effective methodology (Kean and Caletka, 2008).

The other party to the claim - This implies the behaviour of the opposing party to the claims. Determining which technique is the most appropriate to use under given circumstances is a subjective decision, guided by experience, the availability information and other relevant factors.

Skills of the analyst and familiarity with the project - Duties and key professional requirements of a skilful delay analyst can be identified as a detailed knowledge and understanding of a variety of delay analysis techniques is required, major multi-disciplinary, multi contractor infrastructure project experience, demonstrable skills in delay claim management. (Arditi and Pattanakitchamroon, 2006)

Duration of the project - Project duration mostly depends upon the project definition, project implementation and project completion phases of the project life cycle. If the time duration of such phases extends, then automatically project duration will also increase (Ramanathan *et al*., 2012). Sophistication level of the delay analysis method has to be considered here on this factor, because prolongation cost has significant effects through this kind of project.

Complexity of the project - Project complexity can be defined as consisting of many varied interrelated parts and can be operationalized in terms of differentiation and interdependency. Due to consisting of many varied interrelated parts and interdependency activities, single and simple error of delay analysis may ended with a huge loss to the single party of the contract or to the both parties. Therefore, well sophisticated DAT should be adopted when computing delays in complex projects.

The amount in dispute - In order to avoid or at least minimize the conflicting suggestions over the methodology, it is recommended that the interested parties try to agree an appropriate method of analysis before the disputing partied begin their retrospective delay analysis prior to litigation or arbitration has been commenced. Further, in the absence of an agreement, careful consideration should be given in obtaining the decision of the judge or arbitrator as to the appropriateness of the method proposed, before proceeding with a fully delay analysis.

Dispute resolution forum - The dispute resolution forum is the contract clause or agreement in a contract that sets out the process whereby the parties will seek a resolution to any dispute that may arise between them, as well as the venue where the dispute is to be resolved (Ramanathan *et al*., 2012)

Time availability for delay analysis - When comparing retrospective delay analysis techniques, as planned vs as built and impact as planned are the quick and simplest method of analysis. Collapsed as built is also an analysis simple to perform but more time consumption than above and time impact analysis is the most thorough method of analysis, although it is generally the most time consuming and costly when performed forensically (SCL delay and disruption protocol, 2002). Hence, based on the timing constraint for the delay analysis, the most suited DAT must be selected.

Size of the project - As the project size increases, the complexity and the risks of the project will automatically increase. In large projects minimizing global claims is one of the top most aspects of the Engineer (Lovejoy, 2004).

7. Conceptual Framework to Select Most Suitable Delay Analysis Technique for Particular Scenario in Sri Lankan Construction Industry

Through the findings of the literature review and the interviews with experts, a conceptual model to select most suitable DAT for particular scenario was developed. The model takes into account all four main phases of a scenario: Identify the delay type, identify filter factors, select DAT and utility factors. This model is presented in Figure 1. Therefore prior to consider DAT going to use, the analyst should identify which type of delay occurred. Then only analyst can filter out certain techniques according to the context might be the first step prior to taking a decision with the utility factors. After filter out certain techniques from filter factors (as shown in the Figure 1; yes/no situation), selecting a one of the best method from those depends upon the scoring or weightings of DATs and utility factors.If only analyst go through this process, it will help to derive a fair conclusion for all parties involved.

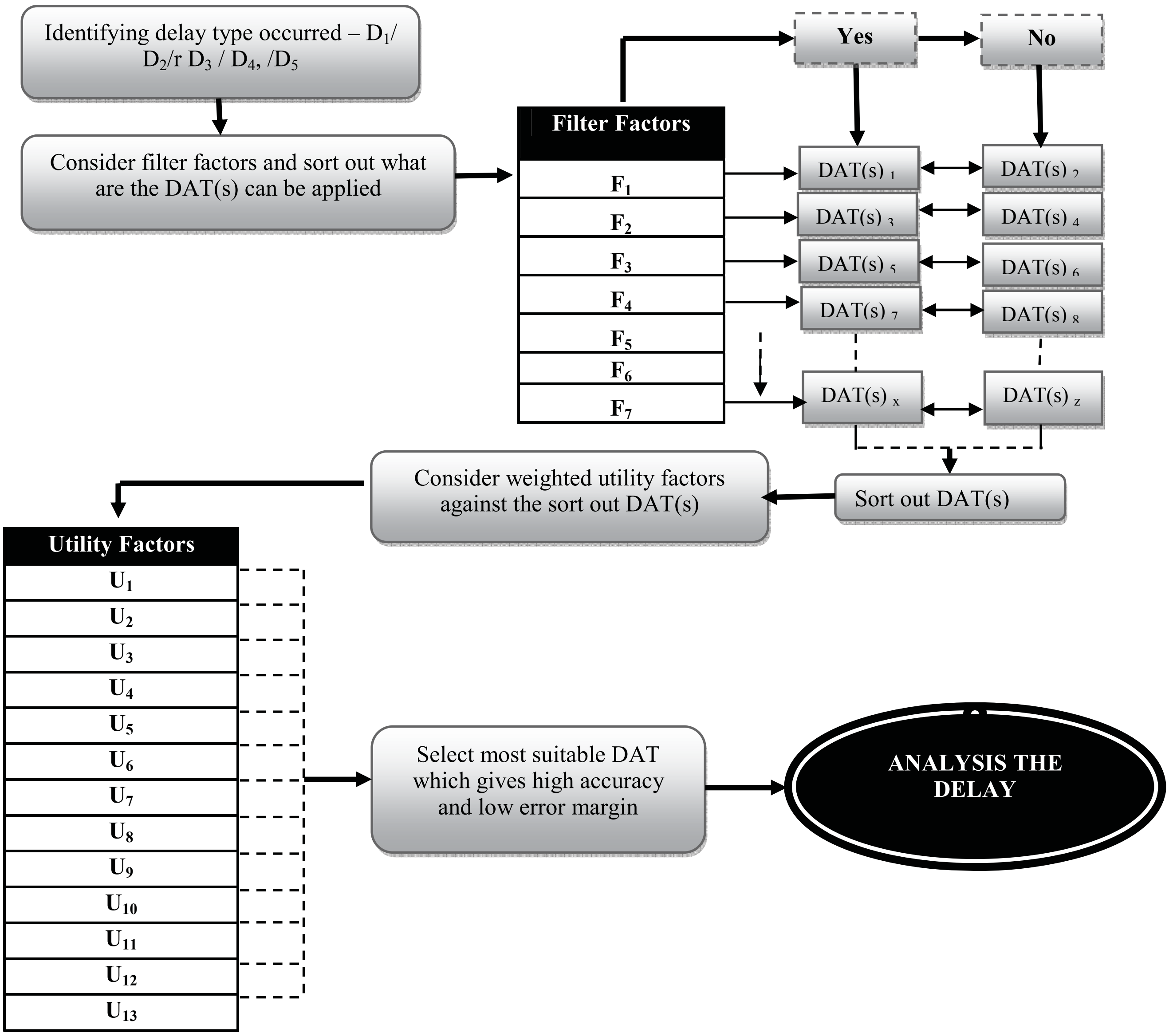

Figure 1: Conceptual Frame Work for Select Most Suitable DAT

7. FUTURE DEVELOPMENT

In order to increase the accuracy level and to decrease the level of error margin, more priority has to be given to the utility factors. Therefore it is need to rank and weight/scoring utility factors according to the Sri Lankan construction industry. In addition to select most suitable DAT among sort out DATs, there should be a comprehensive framework for consider utility factors. As a further development of above conceptual frame work, it going to rank and weight on each utility factors according to the Sri Lankan context and develop more comprehensive model to select most suitable DAT for particular scenario and meanwhile to give fair conclusion for involved parties. As well as ranking it will prioritise identified thirteen utility factors according to the Sri Lankan Context. In addition a frame work will be developed to select best DAT among sort out DAT(s) for particular scenario by using utility factors. Not only that but also it will derive a most suitable new DAT based on field scenario related to building construction industry.

8. CONCLUSIONS

Construction delays are very common in the construction industry. There are various types of Delays such as excusable, inexcusable, compensable, non- compensable and concurrent delays. To analyse and to give fair conclusion for parties who involved in delay analysis process, this process should be a comprehensive process. Within this comprehensive process, the analyst should be able to identify which delay type occurred and then consider seven filter factors to sort out DAT(s) which can be applied for that particular scenario. As a next step of this process, analyst should consider thirteen utility factors to select highly accurate and most error free technique to gives best conclusion for analyse. Proposed conceptual frame work (Figure 1) provides some sort of idea for select most suitable DAT for particular scenario. But to select most accurate method there should be a comprehensive frame work. Therefore, it is crucial at this point of time to develop a comprehensive framework to select most suitable delay analysis technique for particular scenario by considering utility factors in Sri Lankan construction industry. That will be achieved at the of the total research process.

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VIABILITY OF PRIVATE SECTOR INVOLVEMENT IN INFRASTRUCTURE PROJECT DEVELOPMENT IN DEVELOPING COUNTRY

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ABSTRACT

Since public infrastructures underpin economic and social development, infrastructure project development is essential for the sustainable growth of a country. In many developing countries, large scale infrastructure projects are undertaken through conventional public procurement, using bilateral and/or multilateral funding. On the other hand, the financial capacity and practical project management know-how of the private sector is an attractive option for the government for the sustainable construction of new infrastructures from the macro aspect. For example an infrastructure development financed by the private sector is off-balance sheet, enabling the government to invest more public funds for social projects.

The more popular index used for evaluating the economic feasibility is the Economic Internal Rate of Return (EIRR). The calculation of the EIRR does not capture the feasibility or viability of a project when the private sector is involved in its development because the realistic financial and other risks are not sufficiently assessed and incorporated into the analysis. This paper aims to present a framework to assess the viability of public infrastructure projects reflecting the various risks involved in a project by quantifying and incorporating them to the cash flows and the financial analysis.

Keywords: *Private Sector Involvement; Risk Analysis; Viability.*

1. PRIVATE SECTOR INVOLVEMENT IN INFRASTRUCTURE PROJECT

Continuous development of public infrastructures is essential for the sustainable growth of a country. The provision of public service and infrastructure in developing countries has traditionally been the undertaking of the government. However, with increasing population pressures, urbanization and other development requirements, the government's ability to adequately address public needs through the traditional ways has been heavily constrained. This situation led governments worldwide to increasingly look at the private sector to supplement infrastructure investments and provide public services.

The financial capacity and the practical project management know-how of the private sector are now an attractive option for the government for the construction of new infrastructures, which are needed to achieve the national target for the growth of a country. A public sector involved project can be generally identified as a project which is formulated based on a contract between a government/public sector utility on the one side and a private sector company on the other side, for delivering an infrastructure service on payment of user charges. This project scheme is generally expected to give a win-win solution for all stakeholders. According to the Asian Development Bank (ADB) (2009), the rationale for private sector involvement in infrastructure project is mentioned is as follows.

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For the Public Sector (ADB, 2009) - It allows the public sector to derive benefits from the efficiency and effectiveness of the private sector. This is possible because of the following impacts:

Innovation -Private sector involvement allows the government to tap the private sector's capacity to innovate. The government will spell out the services it needs, and the desired outcomes/outputs while the private sector can then introduce solution to meet all of the government's objectives.

Sharing of responsibilities - The government and the private sector share the responsibility of delivering a service depending on each party's expertise.

Finance -Access to private capital frees government capital to be used in projects with higher public policy objectives.

For the Private Sector (ADB, 2009)

Business opportunities -Private sector can have access to business opportunities which were traditionally accessible only to the public sector.

Design and delivering innovative solutions -Allows the private sector to move from just constructing assets according to specified designs, to designing and delivering innovative solutions. There is more room to innovate and offers efficient solutions for the public services.

For the General Public (ADB, 2009)

Combining expertise of public and private entities- Would deliver public services that can better meet the needs of the public without compromising public policy goals and needs.

Protection of public interest -The government would ensure that public interest is protected in projects involving the private sector and that service delivery would meet public needs at the best value for money. The government's focus shifts from providing the service to managing the service provider.

2. KEY TO SUCCESS OF PRIVATE SECTOR INVOLVEMENT

While involving the private sector can be an important option for sustainable economic growth of a country, various types of risks exist in implementing the infrastructure projects. The features and the magnitude of the risks identified for a project are different depending on the project. It is, therefore, necessary to formulate and assess a project from various aspects (World Bank, 2012; Venkata and Mahalingam, 2012; NCPPP, 2012;Puentas, 2012; European PPP Centre, 2013; ADB, 2009; RF&RIS, 2009; WE, 2008; Li *et al.,* 2005; Ranasinghe, 1996a, 1998, 1999, 2000).

Ranasinghe (1998) states that while private-sector participation in infrastructure projects offers substantial benefits, it is also a complex and difficult undertaking that requires a clear understanding of the concepts, and trust between the public and private sectors. The private sector and the public sector often have conflicting objectives. For example (Ranasinghe, 1998):

- While the private investor aims to maximise revenue and maintain positive cash flows, the utility will aim to control revenues to prevent excessive charging and pay only according to results;
- While the private investor aims to minimise operating costs and use project assets to maximise profits, the utility will require that project assets are properly maintained to provide good quality service and are used in ways to maximise economic benefit to the country;
- While the private investor aims to transfer project risks to the utility, the utility will try to transfer project risks to the private investor, and
- While the private investor would like a stable legal environment, the government would like project companies to comply with all present and future laws and policy changes.

The keys to success of a project involving the private sector is as follows (ADB, 2009):

- How the private sector and the public sector can reasonably share the risks,
- How a government (or utility) can prepare a request for project (RFP) in which the private sector is interested, and
- How the final contract between private sector and public sector can be honoured on the long term.

Focusing on the keys to success, this paper will outline a framework to assess the viability of public infrastructure projects, taking into account of the risks associated with the implementation of the project. As highlighted above, as the objectives which are pursued through the implementation of an infrastructure project by the public sector and the private sector are often conflicting, an index or method which assesses project viability and is acceptable to both sectors, would contribute to the success of private sector involvement in public infrastructure project development.

3. RISK ALLOCATION

A component critical to success of any private sector involvement project is the allocation of risks involved in the development of the project. Before allocation of the risks to the party best able to handle them, all risks should be identified.

An illustrative list of risks associated with a project and its consequences as suggested by the ADB (2009) are shown below.

Table 1: Generic Risk Categories (ADB, 2009)

No.	Risk Category	Description of Risk	Direct Consequence
1	Commissioning risk	The risk that the infrastructure will not receive all approvals to satisfy an output specification, such as expected changes in legislation which allows for a specific output specification not materializing	Additional ramp-up costs, cost of maintaining existing infrastructure or providing a temporary alternative solution where this ideas to delay in the provision of the service
2	Construction risk	The risk that the construction of the assets required for the project will not be completed on time, within the budget or to specification	Additional raw materials and labor costs, cost of maintaining existing infrastructure or providing a temporary alternative solution where this ideas to delay in the provision of the service
3	Demand risk	The risk that the actual demand for a service is lower than planned	Reduced revenue
4	Design risk	The risks that the proposed design will be unable to meet the performance and service requirements in the output specifications	Cost of modification, redesign costs
5	Environmental risk	The risks that the project could have an adverse environmental impact which affects project costs not foreseen in the environmental impact assessment	Additional costs incurred to rectify an adverse environmental impact on the project, incurred from the construction or operation of the project or pre-existing environmental contamination
6	Financial risk	The risk that the private sector over-stresses a project through inappropriate financial structuring	Additional funding costs for increased margins or unexpected refinancing costs
7	Force majeure risk	An act occasioned by an unanticipated, unnatural or natural disaster such as war, earthquake or flood of such	Additional costs to rectify

		magnitude that it delays or destroys the project and cannot be mitigated	
8	Industrial relations risk	The risk that industrial relations issues will adversely affect construction costs, timetable and service delivery	Increased employee costs, lost revenue or additional expenditure during delay in construction or services provision (post-construction)
9	Latent defect risk	The risk that an inherent defect exists in the structure being built or equipment used, which is not identified upfront and which will inhibit provision of the required service	Cost of new equipment or modification to existing infrastructure
10	Operating risk (service under performance)	The risks associated with the daily operation of the project, including an unexpected change in operating costs over budget	Increased operating costs or reduced revenue over the project term
11	Performance risk	The risk that the operator will not perform to the specified service level, such as the government authority permitting off-take of less than required demand	Cost of failing to comply with performance standards
12	Change in law risk	The risk that the current regulatory regime will change materially over the project or produce unexpected results	Cost of complying with new regulations
13	Residual value risk	The risk relating to differences from the expected realisable value of the underlying assets at the end of the project	Lower realisable value for underlying assets at the end of the project term
14	Technology obsolescence risk	The risk that the technology used will be unexpectedly superseded during the term of the project and will not be able to satisfy the requirements in the output specification	Cost of replacement technology
15	Upgrade risk	The risks associated with the need for upgrading the assets over the term of the project to meet performance requirements	Additional capital costs required to maintain specified service

Balanced allocation of all the identified risks plays a critical role in the successful implementation of any private sector involved project. The general principle governing risk transfer is that each risk should be allocated to whoever is best able to manage it at the least cost, taking into account public interest considerations. Therefore, optimal rather than maximum transfer of risk needs to be undertaken (ADB, 2009). The important factors to be considered during risk allocation include (ADB, 2009):

- The nature of the project
- The respective strengths and ability of each sector to manage a risk (this may change over time as each sector's risk mitigation skills improve)
- Flexibility of the output specification (whether any constraints exist which influence the method for managing risk)
- Previous levels of risk transfer (this indicates the historical success of each sector in managing particular risks and the potential ability to manage risks in the future)
- Prevailing market attitudes towards risk
- Public interest factor

- Other policy considerations
- External environment, economic scenario, risk appetite of foreign institutions

4. ASSESSMENT OF PROJECT VIABILITY

After identification of risks/formulation of the projects, the next important activity is assessing their financial viability. The financial analysis would determine the viability of the project given the cash flows of the costs involved and the expected revenues.

4.1. PROJECT COST

The key input for the financial feasibility analysis is the project cost and it is the variable that is best defined at this stage of the project. Three broad categories of costs are considered, that is, capital costs for project development and operation and maintenance costs which arise during the operation and maintenance of the constructed infrastructure or asset. ADB (2009) defines them as follows.

CAPITAL COSTS

Capital costs for the development of projects would include basic capital costs on buildings required for the project, including any fit-out costs required to convert an existing property to the required use. Land acquisition cost would include specific costs on assets across the value chain, which needs to be created. Cost estimates should reflect the full resource costs of the project (ADB, 2009).

It is to be noted here that the estimation of capital costs should also include the opportunity cost of assets already owned by the institution and which are to be used in the project. If the asset could be sold or used for another purpose, then the use of that asset in the project has an opportunity cost. The main heads of capital costs for a typical project is given below (ADB, 2009).

- Land acquisition cost
- Construction costs
- Installation of electro-mechanical equipments
- Contingency reserve
- Preliminary and pre-operative expenses
- Interest during construction
- Operation and maintenance to be capitalized

OPERATING COSTS

In addition to consideration of the capital costs to be incurred for the creation of an asset, the project cost estimation should also include the costs on operation of the assets created, such as:

- Raw material purchase charges
- Power consumption charges
- Input costs of consumables for assets operation
- Cost of employees directly involved in service delivery includes wages and salaries, employee entitlements, superannuation, training and development, etc.
- Administration expenses
- Insurance costs

The operating costs would be identified on the basis of the demand projections and the rates of operating costs identified on the basis of current market rates or rates paid in recent similar projects (ADB, 2009).

MAINTENANCE COSTS

In addition to considering the operational costs of the assets, it is equally important to take into account the expenses relating to the maintenance of the assets created. These costs largely relate to the regular civil works which need to be undertaken for maintaining the life of the asset. These civil works therefore include repair works and minor replacements. These maintenance costs are recurring in nature and will be linked to maintaining the capacity and quality of the asset rather than upgrading or improving assets. Maintenance cost typically includes raw materials (spares), tools and equipment and employee costs associated with maintenance work (ADB, 2009).

A combination of the capital costs and the operation and maintenance expenses on the identified project would indicate the total investment costs on the project in constant value terms.

DUE DILIGENCE OF PROJECT COSTS

This activity involves reviewing the definition of project costs, both capital and operational/ maintenance, to ensure that they conform to some minimum tests of reliability, credibility and consistency so as to be acceptable to the prospective bidders. A description of some of the important parameters for the review of project costs is as follows (ADB, 2009).

Inflation: The costs of individual items considered for arriving at the final cost should reflect current market prices. The implications of unrealistic assumptions on inflation/omission of inflation are that the cost estimates would be lower and would not reflect the current level of prices.

Opportunity Cost: In case the sponsor is deploying its own resources - men, machinery or funds-in the project, then the opportunity cost (the return foregone by the sponsor by not deploying these resources profitably elsewhere, including its own operations) will need to be considered as the cost of the resource. The implications of omitting opportunity costs in the cost estimates are that the cost estimates would be under reported, inflating the feasibility of the project. However, the project will then not be comparable with the private sector reference.

Total Project Cost: The basis or assumptions for the estimation of the project costs needs to be verified. According to Ranasinghe (1996b), the items considered for arriving at the total project cost are:

- Base costs (capital, operating and maintenance) in constant value terms;
- Escalation During Construction (EDC) to reflect the impact of inflation as current market prices;
- Interest During Construction (IDC) to account for the borrowed funds.

4.2. PROJECT REVENUES

Project revenues represent the income that is generated from the provision of service supply to the user. It should be noted that inflows of a revenue nature will be considered as project revenues. Any inflow of a capital nature would be added to the project funding or reduced from the gross cost of the project, depending on its accounting nature (ADB, 2009).

The revenues may be bifurcated into two broad categories-direct revenues and indirect revenues. Direct revenue is single, largest and the most important component of revenue generated from the provisioning of services to the users. In addition to the direct sources of revenue, the public sector may also explore the indirect revenue sources such as Real Estate Revenues, that is, possibility of increase of the real estate value of the municipalland within its possession due to development of the project (ADB, 2009).

The sum total of the above revenue streams would be projected in the financial analysis for the project.

4.3. *FINANCIAL MODEL*

The financial viability of any capital-intensive project is defined by the returns on investment. Therefore, one of the key objectives behind the preparation of a financial model is to estimate the returns that the project can generate in the future. These returns are calculated on the basis of project cash flows, which are available to both equity and debt investors who have invested in the project (Ranasinghe, 1998, 1999).

The financial model includes:

- Calculation of project cash flows;
- Calculation of project net present value (NPV) at minimum acceptable rate of return (MARR)
- Calculation of project internal rate of return (IRR)

For the financial model, some basic assumptions and inputs need to be considered. The inputs and assumptions are listed below (ADB, 2009).

- Project cost including capital costs, preoperative expenses (to be capitalized), fees of the transaction advisor (if any),cost of legal approvals, etc. In addition, the phasing of the capital expenditure also needs to be defined.
- Project revenues including the revenues which have been identified from all the sources
- Operations and maintenance costs as per the demand projections and the estimated operating expenses
- Certain assumptions for projecting the cash flows in the future, for instance, long-term inflation rates, long-term interest rates, income tax rates in the future, etc.

For the calculation of the project cash flows, the following key statements would have to be prepared (ADB, 2009):

- Projected Profit and Loss Account
- Projected Balance Sheet
- Projected Cash Flow statement (showing calculations of the project cash flows)
- A statement of the assumptions used across the financial statements
- Total capital expenditure and its phasing

These five financial statements will constitute the basic financial model of the project. Generally, the financial statements listed above are projected to cover the economic life of the created asset so as to consider the costs of the complete project life cycle (ADB, 2009).

4.4. *ASSESSMENT OF PROJECT VIABILITY*

The private sector investor would invest capital in a project contract as a business investment. This means that there is an expectation of attractive returns from the investment that the private investor has made. The key question therefore to assess the commercial viability is to determine whether the returns available from the project are attractive enough for a private investor.

NET PRESENT VALUE (NPV)

Net present value (*NPV*) is used to determine the difference in present value of cash flows of future project revenues and costs in today's value, usually represented as time zero in a cash flow diagram. In other words, it is the value obtained by discounting the annual cash outflows and inflows accruing throughout the life of an infrastructure project at a constant minimum acceptable rate of return (*MARR*). Then, the fundamental relationship to determine the *NPV* of an alternative is given by,

$$NPV = \sum_{i=0}^{n} \frac{B_i - C_i}{(1+r)^i} \tag{1}$$

Where B_i and C_i are the benefits (revenues) and costs of the i^{th} year and r is the discount rate respectively.

In choosing between alternatives, the criterion is to select the one that maximises NPV. For instance, a NPV of \$ z means that the PV of the alternative is \$ z greater than on an investment of similar size that produces a rate of return equal to the MARR. A negative PV means that the alternative does not satisfy the rate of return requirement, as MARR reflects the opportunity cost of capital. In other words, the possible returns an investor would obtain on the same amount of capital if invested elsewhere, assuming that the risks are similar for both investment alternatives is higher.

INTERNAL RATE OF RETURN (IRR)

The IRR calculates the return on the investment in a project as a non-dimensional measure. Present value formulations are the foundations for IRR calculation which is calculated by equating NPV of cash flows to zero and solving for the discount rate that allows the equality. Therefore, IRR is defined as the rate at which NPV is equal to zero. The IRR estimated would therefore have to be compared against a benchmark to assess whether the project is commercially viable. The possible benchmarks, MARR, could be returns that are generated through similar projects or returns that are assumed to be reasonable by a private investor. In order to identify whether a project is commercially viable or not, the following index called Weighted Average Cost of Capital(WACC) is suggested in ADB (2009). The WACC is a minimum return that a project must earn on its asset base to satisfy its creditors, owners, and other providers of capital.

5. RECOMMENDATION

The keys to success of a project involving the private sector was identified previously as to how, the private and public sectors can reasonably share the risks, a RFP in which the private sector is interested can be prepared, and how the final contract between the two sectors can be honoured on the long term.

While NPV and IRR are indices which are utilized for economic or financial evaluation of capital investment projects, this study will attempt to understand the concept of these indices and to research how more adequate/realistic cash flows for the cost and the revenue can be estimated taking into account of the risks associated in respective infrastructure projects.

High return or profitability is not necessarily expected from or required for infrastructure projects which are undertaken by a government because of their public nature. Therefore, reasonable assumptions in the cash flows for the economic/viability evaluation, for example, the benefit amount expected from a project after the completion of the asset can be assumed up to the end of the project life. Other uncertain factors (risks) from the long term aspect, such as variation of inflation and interest rate based on the local and international economic trends, deterioration of asset value, adequacy of demand projection, may not be incorporated into the cash flow analysis.

When the project returns are not found to be attractive for a RFP, the possibility of obtaining an additional grant to fund the costs of the project may be explored. Typically, if the returns on a project are found to be unattractive, the viability of the project may be enhanced by considering the option of a subsidy (viability gap fund) by the public sector. Ranasinghe (1999) developed a spreadsheet-based model that can be used for viability analysis of an infrastructure project.

The key factor to be considered in the viability analysis is how the various risks identified in Table 1 are quantified and incorporated into the cash flow calculations. Some concepts for quantification of risks and incorporation into the financial model suggested by the ADB (2009) are given below.

- Risk is a possibility/potential but is equivalent to cost if it is materialized.
- Conversion of the extent of risks to cost value, considering the direct consequence and type of risk.
- Risk converted to cost value is presented as an expected value assuming the probability of

occurrence

- In parallel with assumption of risk, if risk mitigation measure available will be considered, the net cost for risk will be the difference between the whole cost for risk and the cost required for the mitigation measure

Hence, project viability analysis would include correcting the estimated cash flows (revenue and costs) by incorporating various risks and estimating the subsidy ratio necessary to make the public infrastructure projects viable to provide the service to the consumers at a reasonable cost. Type and weight of risks to be considered in evaluating a public infrastructure under PPP scheme will be different by the nature of the project and the implementation mode. The future of this study will eventually propose a methodology to identify/select the specific risks to be considered for evaluation of a project, to quantify them and to incorporate into the economic evaluation, to formulate the viability of water supply projects to be implemented applying PPP method.

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